SYSTEMATICS, ETHNOBOTANY AND CONSERVATION OF THE GENUS *Kalanchoe* Adans. (CRASSULACEAE) IN KENYA

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DECLARATION

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This thesis is my original work and has not been presented for a degree in any other university or for any other award.

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DEDICATION

This work is dedicated to my loving spouse, Eric Juma Khatete, wonderful children—Faith Pendo, Prudence Neema, Joseph Baraka, Nathan Amani, Purity Vugutsa and Esther Juma—and my dear mother Jane Muhembi Lidambitsa.

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ABBREVIATIONS AND ACRONYMS

A	Significance Level
AOO	Area of Occupancy
APG	Angiosperm Phylogeny Group
CA	Cluster Analysis
CAM	Crassulacean Acid Metabolism
CNS	Central Nervous System
COVID	Coronavirus Disease
CR	Critically Endangered
CTAB	Cetyltrimethylammonium Bromide
D	Error Estimate Limit
DNA	Deoxyribonucleic Acid
EA	East African Herbarium
EN	Endangered
EOO	Extent of Occurrence
EW	Extinct in the Wild
FAO	Food and Agriculture Organization
FC	Frequency of Citation
FL	Fidelity Level
FTEA	Flora of Tropical East Africa
GBIF	Global Biodiversity Information Facility
GeoCAT	Geospatial Conservation Assessment tool
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
ICF	Informant Consensus Factor
ITS	Internal Transcribed Spacer
IUCN	International Union for Conservation of Nature
K	Royal Botanical Garden, Kew Herbarium

KDHS	Kenya Demographic and Health Survey
LC	Least Concern
LPP	Local Posterior Probability
ML	Maximum Likelihood criterion
MPOX	Monkeypox
MSC	Multispecies Coalescent
N	Number of Informants Interviewed
n	The Number of Informants (that use the plants as medicine to treat any given disease)
NHM	Natural History Museum
NT	Near Threatened
Np	The Number of Informants that claim to the use of a plant species to treat a particular disease
Nt	Total Number of plant taxa used for a particular disease category
NTSYS	Numerical Taxonomic and Multivariate Analysis
Nur	Total Number of Use Reports mentioned for a particular disease category
OTU	Operational Taxonomic Unit
P	Proportion of Population
PAST	Palaeontological Statistics
PAUP*	Phylogenetic Analysis Using Parsimony
PCA	Principal Component Analysis
PCR	Polymerase Chain Reaction
POWO	Plants of the World Online
RAPD-PCR	Random Amplified Polymorphic DNA-Polymerase Chain Reaction
RFC	Frequency of Citation
SPSS	Statistical Package for the Social Sciences
TB	Tuberculosis

TDWG	Biodiversity Information Standards
U	Number of Uses Mentioned by the Participants for a Given Species
UA	Univariate Analysis
UPGMA	Unweighted Pair-Group Method Using Arithmetic Averages
USA	United States of America
UV	Use Value
VU	Vulnerable
WHO	World Health Organization
$Z\alpha/2$	Standard Normal Distribution Values

ABSTRACT

Kalanchoe Adans. (Crassulaceae) comprises about 175 succulent species, native to tropical Africa and Madagascar with 19 occurring in Kenya. Most (68.4%) remain unassessed for conservation status and their taxonomy and phylogeny are unclear due to morphological variation, hybridisation, polyploidy and overlapping distribution. Although used as ornamentals and medicinal plants in many parts of Africa, the uses of *Kalanchoe* species in East Africa have not been systematically documented. The objectives of this study were to clarify species boundaries within the *K. lateritia* and *K. nyikae* complexes, determine their phylogenetic relationships using molecular and morphometric analyses, document the traditional uses and assess conservation status. Morphological data obtained from herbarium specimens was analysed using PAST programs while molecular studies utilized DNA extraction from leaf samples using EZNA kits, sequencing of the data through the Angiosperm 353 probe kit, and analysing it under the maximum likelihood criterion. Ethnobotanical data was collected using interviews and semi-structured questionnaires in six flora regions. Conservation status was evaluated based on field observations of threats, Area of Occupancy (AOO), and Extent of Occurrence (EOO) through Geospatial Conservation Assessment Tool (GeoCAT). Taxonomic findings indicated *K. nyikae* as monophyletic supporting its subspecies, *K. nyikae* subsp. *auriculata* as valid rather than a hybrid. Conversely, *K. lateritia* varieties revision was highlighted, combination of *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* into one variety/subspecies and retention of K. *lateritia* var. *pseudolateritia* as a separate variety/subspecies. Phylogenetic analyses resolved two main clades, confirming *Kalanchoe* as broadly monophyletic, and *K.* subg. *Kitchingia* and *K.* subg. *Bryophyllum* polyphyletic. *Kalanchoe* exhibited uncertain relationships among six subclades. The study revealed that *Kalanchoe* species in Kenya are mainly used as ornamentals and in traditional medicine for treating injuries, wounds, gastrointestinal problems and infections in humans and poultry. *Kalanchoe prittwitzii*, *K. densiflora* and *K. lateritia* were most cited. Conservation assessments categorised three species as critically endangered (CR), 12 as Endangered (EN) and four as Vulnerable (VU), under IUCN (2022) criteria. A comprehensive evaluation upgraded *K. lateritia* and *K. nyikae sensu stricto* to EN from LC due to their low AOO resulting from severely fragmented or few localities and ongoing decline–criterion 2ab (iii) and significant habitat threats. The threats include habitat loss, anthropogenic activities and prolonged drought and floods. Findings from this study emphasize the need for clear species delimitation to support identification, management, and sustainable utilisation. Conservation efforts should focus on raising awareness, sustainable use, and inclusion in *in-situ* and *ex-situ* conservation initiatives. Taxonomic revision, further research using other molecular tools and broader sampling to refine phylogenetic and taxonomic relationships, phytochemical studies of the medicinal species and IUCN red list update are recommended.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Vague systematics of plants with incomplete ethnobotanical and conservation statuses records in the Genus *Kalanchoe* Adans. limits their scientific investigations, sustainable utilisation and conservation strategies. The genus consists of about 175 accepted—that is, species currently recognised as valid in taxonomic literature—including succulent-leaved shrubs and perennial herbs, a few annuals or biennials and rare occurences of subshrubs (Smith, 2025; POWO, 2025). *Kalanchoe* species are morphologically attractive—characterised by their colourful flowers and uniquely shaped mottled leaves—and are widely utilized for both ornamental and medicinal purposes (Assis de Andrade, 2023; Nascimento *et al*., 2023). The genus is native to eastern, central and southern Africa, as well as the Island of Madagascar (Smith and Shtein, 2022; Vargas *et al*., 2022), with its distribution extending to Arabia, Brazil and parts of tropical Asia and only one species occurring in tropical America (Eggli, 2003; Smith, 2022; Tian, 2021).

Kalanchoe plants typically exhibit erect inflorescences with colourful (red, yellow, pink, beige) flowers arranged in corymbs of cyme, a calyx with lobes shortly connate at the base, and two whorls of eight stamens with filaments attached to at least half of the corolla tube lengthwise (Wickens, 1987; Agnew, 2013; Laskar *et al*., 2023). Indeed, many *Kalanchoe* species possess significant potential for further development within Kenya’s ornamental

and floriculture industry—one of the country's key export sectors and major source of foreign exchange, despite being dominated by rose production.

The recognition of the genus *Kalanchoe* as distinct from *Bryophyllum* Salisb. and *Kitchingia* Baker has long been debated (Berger, 1930; Lauzac-Marshal, 1974; Wickens, 1987). Traditional classifications based on floral and vegetative characters have proven inadequate, due to significant overlap among these characters (Wickens, 1987). For instance, Wickens (1987) distinguished *Kalanchoe* based on the position and adhesion of the stamen-filaments on the corolla tube. However, these characters exhibit considerable variation, complicating infrageneric clarifications and obscuring relationships within the genus (Wickens, 1987). This taxonomic uncertainty has driven further research efforts (Smith and Figueiredo, 2018; Tian *et al*., 2022; Rodewald *et al*., 2025).

Systematics relationships among *Kalanchoe* of Kenya viz. *K. aubrevillei* Raym.-Hamet ex Cufod., *K. ballyi* Raym.-Hamet ex Cufod., *K. bipartita* Chiov., *K. boranae* Raadts, *K. citrina* Schweinf., *K. crenata* (Andrews) Haw., *K. densiflora* Rolfe, *K. fadeniorum* Raadts, *K. germanae* Raym.-Hamet ex Raadts, *K. glaucescens* Britten, *K. laciniata* (L.) DC. *K. lateritia* Engl., *K. lanceolata* (Forssk.) Pers., *K. marmorata* Baker, *K. mitejea* Leblanc and Raym.-Hamet, *K. ndotoensis* L.E. Newton, *K. nyikae* Engl., *K. obtusa* Engl., *K. prittwitzii* Engl. remains unresolved because of extensive hybridization, polyploidy, and morphological overlaps (Mort *et al*., 2009; Chernetskyy, 2011; Karimi *et al*., 2021). The taxonomic difficulty is further compounded within species complexes such as *K. lateritia*

and *K. nyikae*, where varietal and subspecific distinctions are primarily based on subtle vegetative and floral traits.

While molecular phylogenetic studies have improved the resolution of *Kalanchoe*'s classification, they have largely excluded or only incorporated a few samples from Africa, leaving gaps in our understanding of the genus (Gehrig *et al.,* 2001; Rodewald *et al*., 2025). Given these taxonomic and phylogenetic complexities and inadequacies, further morphological and molecular studies are essential for refining relationships and ensuring accurate species identification and conservation efforts.

Although species of *Kalanchoe* are widely used across Africa for wound care, inflammation and diverse traditional remedies, contemporary, well documented ethnobotanical records and up-to-date pharmacological studies that map which species are used where, how they are prepared, and their safety remain limited— hindering efforts to validate, conserve, and responsibly integrate *Kalanchoe* knowledge into modern healthcare (Stefanowicz-Hajduk *et al*., 2020; Assis de Andrade *et al*., 2023; Faundes-Gandolfo *et al*., 2024). Documenting the contemporary uses of *Kalanchoe*, can help identify new sources of affordable medicinal and commercial products because several species have already been scientifically validated for specific bioactive properties (Kumari *et al*., 2022; Ali *et al*., 2023; Chebii, 2023). For example, *K. pinnata* (Lam.) Pers. has yielded bufadienolides and flavonoids with demonstrated anti-inflamatory, anticancer, antidiabetic, antiviral and antimicrobial activities, some of which are being explored for phytotherapeutic formulation (Fernandes *et al*., 2019; Assis de Andrade *et al*., 2023).

Likewise, *K. daigremontiana* Raym.-Hamet ex H. Perrier and *K. gastonis-bonnieri* Raym.-Hamet ex H. Perrier have shown antimalarial, antiviral (including anti-HIV), and wound-healing potentials, supporting their integration into ethnobotanical-guided drug discovery programmes (Barbosa *et al*., 2012; Agarwal and Shanmugam, 2019; Amalia *et al*., 2022; Mejia-Mendez *et al*., 2023).

By linking these validated species-specific properties to local knowledge and use patterns, current ethnobotanical documentation can guide targeted bioprospecting and the development of safe, accessible plant-based products. However, despite these benefits, many species remain overlooked, little-known, and underutilized within their native range (Smith and Figueiredo, 2019, 2020). *Kalanchoe* species such as *K. lateritia* and *K. obtusa* are reportedly used in traditional medicine and as charms (Pakia *et al*., 2003; Waisindye *et al*., 2016; Kołodziejczyk-Czepas and Stochmal, 2017). In line with their medicinal applications and in accordance with the WHO 2014–2023 Traditional Medicine Plan (WHO, 2017), it is essential to conserve and promote the sustainable use of native *Kalanchoe* species (WHO, 2019; Chebii *et al*., 2020; Nascimento *et al*., 2023).

Unlike previous studies that have only documented *Kalanchoe* species as part of broader surveys on regional medicinal plants—mainly in the Rift Valley and Western Kenya (Kigen *et al*., 2017)—the current study provides a focused ethnobotanical investigation, of the genus *Kalanchoe* across multiple regions in Kenya. While earlier research in Kenya mentioned only two species—*K. densiflora* and *K. marmorata*—for their medicinal uses (Kipkore *et al*, 2014; Odongo *et al*., 2018; Kigen *et al*., 2019), this study expands the scope

by documenting additional species, their cultural applications and associated ecological and conservation status. Nonetheless, studies on *K. densiflora* and *K. pinnata* in Kenya identified the presence of potentially bioactive phytochemicals (Kirui *et al*., 2014; Waititu *et al*., 2018). Outside Kenya, species such as *K. crenata*, *K. laciniata* and *K. lanceolata* (Forssk.) Pers. and *K. pinnata* have been used to manage inflammation, infections and headache in humans (Smith *et al*., 2019; Omara, 2020; Fokou *et al*., 2024). Inadequate ethnobotanical knowledge of *Kalanchoe* remains a challenge, hence the need to document the ethnobotany of the species in Kenya for preservation of their cultural heritage.

Beyond their use in management of human diseases, *Kalanchoe* are also used in ethnoveterinary medicine for treating poultry (Agbédé *et al*., 1993; Richwagen *et al.*, 2019). However, in recent years, habitat loss and overexploitation have posed significant threats to succulent plants in general and *Kalanchoe* in particular (Friis *et al.*, 2017). For instance, *K. fadeniorum* Raadts, known only from Kenya and Somalia, is likely extinct in the wild; others, like *K. ballyi* Raym.-Hamet ex Cufod. and *K. peteri* Werderm. are threatened with extinction (Ngumbau *et al.*, 2020; IUCN, 2025).

The rate of habitat loss and environmental degradation within the *Flora of Tropical East Africa* (*FTEA*) is alarming (Stévart *et al.*, 2019; Couvreur *et al.*, 2021; Ogwu *et al.*, 2021), driven by increasing demand for agricultural, settlement, infrastructural developments, fuel, construction as well as fodder for livestock production (Kipkore *et al*., 2014; Mutwiwa *et al*., 2018; Githitho, 2021; Musyoka, 2021). Many *Kalanchoe* species populations are declining in the coastal and other disturbed habitats (Githitho, 2021).

However, conservation assessments remain limited, with only six of the 19 Kenyan *Kalanchoe* having been evaluated to-date (IUCN, 2025). These include *K. ballyi* (EN), *K. densiflora* (LC), *K. fadeniorum* (EW), *K. lateritia* (LC), *K. nyikae* (LC), *K. obtusa* (VU).

Furthermore, a number of existing assessments were based on old data collected over two decades ago, hence the need to update the conservation status in consideration of habitat shifts and conditions in areas of occurrence (Blundel *et al*., 1982; Walter and Gillett, 1998; IUCN, 2025). Addressing these knowledge gaps is crucial for prioritising *Kalanchoe* species in conservation and resource management strategies.

This study aimed to clarify taxonomic and phylogenetic relationships among *Kalanchoe* taxa with the aim of resolving species complexes within *K. lateritia* and *K, nyikae* using morphological and molecular data, document the ethnobotanical uses and local names of *Kalanchoe* species in Kenya and update their conservation status.

1.2 Statement of the Problem

The genus *Kalanchoe* remains poorly understood in Kenya due to limited and incomplete information on its taxonomy, phylogeny, ethnobotanical uses and conservation status. Globally and nationally, existing systematic data are insufficient to support evidence-based conservation and sustainable utilisation of its species (Nascimento *et al*., 2023). This lack of comprehensive knowledge constrains effective management of the genus despite its ecological, cultural and economic importance.

Taxonomic uncertainity is a major challenge. Morphological overlaps and a lack of well-defined synapormorphic characters has complicated species identification, leaving several *Kalanchoe* Kenyan species−particularly within the *K. lateritia* and *K. nyikae* complexes—poorly delimited (Wickens, 1987: Chernetskyy, 2011; Karimi *et al*., 2021). For instance, *K. lateritia* var. *prostrata* Raadts and *K. lateritia* var. *lateritia* Engl. differ in stem posture and hairiness, yet they share overlapping corolla-tube lengths (8.5–12 mm), while *K. lateritia* var. *pseudolateritia* Raadts displays a slightly longer tube (approximately 14 mm).The main characters used to distinguish the varieties are outlined in Table 1.1.

Table 1.1. Distinguishing Characters of *K. lateritia* Varieties According to the *FTEA*

Variety Name	Stem Habit	Leaves & Stem Indumentum	Other Note
Kalanchoe lateritia* var. *lateritia	Erect	Pubescent (Hairy/Glandular)	Typical, widespread form.
Kalanchoe lateritia* var. *prostrata	Prostrate (Trailing)	Glabrous (Smooth)	Distinctive prostrate habit.
Kalanchoe lateritia* var. *pseudolateritia	Erect (Implied)	Pubescent (Implied, similar to *K. lateritia* var. *lateritia*)	Distinguished by a slightly longer corolla tube.

(Wickens, 1987)

Similarly, *K. nyikae* subsp. *nyikae* Engl. and *K. nyikae* subsp. *auriculata* Raadts differ in leaf attachment and margin traits, yet again, these characters' exhibit degrees of overlap that hinder conclusive differentiation. The key characters used to distinguish the taxa are outlined in Table 1.2.

Table 1.2. Distinguishing Characters of *K. nyikae* Subspecies According to the *FTEA*

Subspecies Name	Leaf Base Morphology	Description
K. nyikae* subsp. *nyikae	Peltate	The petiole is attached near the center of the leaf blade, on the underside, not at the edge. The leaf blade appears like a small shield (*pelta*).
K. nyikae* subsp. *auriculata	Auriculate or Cordate	The leaf blade is attached at the margin, and the base has two small, ear-like lobes (*auricles*) or is heart-shaped (*cordate*).

(Wickens, 1987)

Although molecular studies have improved classification in other regions, African representatives of the genus remain under-sampled, resulting in unresolved systematic relationships (Gehrig *et al*., 2001; Rodewald *et al*., 2025). These gaps impede the determination of species boundaries and obscure evolutionary patterns needed to guide conservation.

Ethnobotanical information on *Kalanchoe* in Kenya is also incomplete. While the genus is widely used in African traditional medicine and several species contain bioactive compounds such as flavonoids with potential therapeutic value (Bogucka-Kocka *et al*., 2018; Fernandes *et al*., 2019; Amalia *et al*., 2022), most Kenyan records come from broad medicinal surveys. Only five species—*K. densiflora, K. crenata, K. lateritia, K. marmorata* and *K. obtusa*—are documented with one or two uses (Pakia, 2001; Kokwaro 2001; Kipkore *et al*., 2014; Odongo *et al*., 2018; Kigen *et al*., 2019), leaving significant gaps in local knowledge. This limits scientific validation, sustainable utilisation, and benefit-sharing opportunities.

Conservation concerns further underscore the need for updated knowledge. Habitat loss, overexploitation and insufficient protective measures threaten several *Kalanchoe* species, with *K. fadeniorum* likely extinct in the wild (Ngumbau *et al*., 2020; IUCN, 2025). However, most *Kalanchoe* species in Kenya lack recent conservation assessments; preventing informed policy decision and prioritisation.

1.3 Justification

The ecological, cultural, and economic importance of *Kalanchoe* species in Kenya contrasts sharply with the substantial gaps that persist in their systematics, ethnobotanical documentation, and conservation status. These gaps impede scientific research, sustainable utilisation, and evidence-based conservation planning, thereby justifying the need for a comprehensive, interdisciplinary investigation. Taxonomic uncertainties driven by hybridisation, ploidy variation, and extensive morphological overlap continue to complicate species delimitation and hinder accurate identification (Wickens, 1987: Descoings, 2003). Unresolved relationships within species complexes such as *K. lateritia* and *K. nyikae* further constrain the development of effective conservation and management strategies, demonstrating the limitations of traditional morphology-based classification and the need for integrative molecular approaches. In addition, ethnobotanical knowledge on *Kalanchoe* in Kenya remains fragmented and under-documented despite the widespread medicinal and ornamental uses of these species. The absence of comprehensive national records restricts scientific validation, pharmaceutical research, and equitable benefit-sharing in accordance with the Nagoya Protocol (Buck and Hamilton, 2011; Glowka and

Normand, 2013). Conservation concerns further heighten the urgency of the study, as succulent species face escalating threats from habitat loss, overexploitation, and environmental degradation (Friis *et al*., 2017; Ngumbau *et al*., 2020; Githitho, 2021). Notably, 68.4% (13) of Kenyan *Kalanchoe* species remain unassessed, and recent cases such as the extinction of *K. fadeniorum* in the wild highlight critical knowledge gaps (Couvreur *et al*., 2021; Ogwu *et al*., 2022). Moreover, the economic potential of native *Kalanchoe* species is largely untapped due to limited taxonomic authentication and inadequate documentation of their uses. For these reasons, this study is justified as a timely, necessary step toward resolving key gaps in taxonomy, ethnobotany, and conservation science and supporting the sustainable utilisation and long-term conservation of *Kalanchoe* species in Kenya.

1.4 Research Questions

i. In what ways can molecular and morphometric approaches clarify species boundaries within the *K. lateritia* and *K. nyikae* complexes?
ii. How does phylogenetic analysis contribute to understanding the evolutionary relationships among *Kalanchoe* species in Kenya?
iii. To what extent do undocumented or lesser-known ethnobotanical uses of *Kalanchoe* species reflect cultural and regional diversity across Kenyan communities?
iv. How is the conservation status of *Kalanchoe* species in Kenya influenced by ecological factors and human activities?

1.5 Hypotheses

i. Morphological variation among *Kalanchoe* species in Kenya is not fully congruence with molecular phylogenetic relationships within the *K. lateritia* and *K. nyikae* species complexes.

ii. Molecular phylogenetic analysis will show that Kenyan *Kalanchoe* species do not form distinct monophyletic clades among other global *Kalanchoe* taxa.

iii. The diversity of documented ethnobotanical uses of *Kalanchoe* species in Kenya is significantly lower than the actual range of uses identified through community-based field surveys.

iv. Conservation assessment of *Kalanchoe* species in Kenya will reveal that at least one species exhibits trends indicative of potential threat status under IUCN criterion.

1.6 Objectives

The study was guided by the listed objectives.

1.6.1 General Objective

To evaluate species boundaries, resolve phylogenetic relationships using molecular data, document the ethnobotanical uses and assess the conservation status of *Kalanchoe* species in Kenya.

1.6.2 Specific Objectives

i. To delineate species boundaries within the *K. lateritia* and *K. nyikae* species complexes based on molecular and morphometric approaches.

ii. To resolve phylogenetic relationships among the *Kalanchoe* species in Kenya.

iii. To evaluate the ethnobotanical uses of *Kalanchoe* species in Kenya.

iv. To assess the current conservation status of the genus *Kalanchoe* in Kenya.

1.7 Significance of the Study

This study is significant because it generates foundational knowledge that advances biodiversity conservation, sustainable utilisation, and scientific understanding of *Kalanchoe* species in Kenya. By integrating molecular and morphological analyses, the study refines taxonomic and phylogenetic relationships, yielding clearer species delimitation and improving the accuracy of identification frameworks essential for conservation management, ecological assessment, and the authentication of plant materials used in subsistence, medicinal, and industrial contexts. The research also makes an important cultural contribution by producing a comprehensive ethnobotanical dataset that preserves indigenous knowledge, supports its intergenerational transmission through documentation and community engagement , and aligns with global efforts by the World Health Organization to strengthen the role of traditional medicine within contemporary healthcare systems (WHO, 2023). The validated ethnomedicinal information further provides a scientific basis for future pharmacological investigations, with potential applications in addressing major public health challenges such as malaria, HIV/AIDS,

COVID-19, and MPOX (Aurora *et al*., 2022; Nascimento *et al*., 2023). Economically, the study identifies native species with high ornamental and commercial potential, thereby supporting Kenya's bioeconomy and enhancing livelihood opportunities for local communities (Mackenzie *et al*., 2018; Kahraman *et al*., 2022). In addition, the findings contribute to the strengthening of national access and benefit-sharing mechanisms under the Nagoya Protocol (CBD, 2022). From a conservation and policy perspective, the study provides updated evidence on species distribution, population trends, and ecological threats, offering critical insights for conservation planning to ensure availability of the plants, environmental decision-making, and the fulfillment of Kenya's commitments under the Convention on Biological Diversity and the United Nations Sustainable Development Goals, particularly SDG 15 (Life on Land). It also provides updated conservation assessment records for IUCN red lists update to safe guard the threatened biodiversity.

1.8. Conceptual Framework: Interdisciplinary Approach to *Kalanchoe*'s Ethnobotany, Conservation and Systematics

Understanding *Kalanchoe* requires a combination of ethnobotany, conservation, taxonomy, and phylogenetics studies. Ethnobotany, conservation, phylogeny, and taxonomy are interconnected disciplines that play a crucial role in understanding and conserving biodiversity as shown in Figure 1.1.

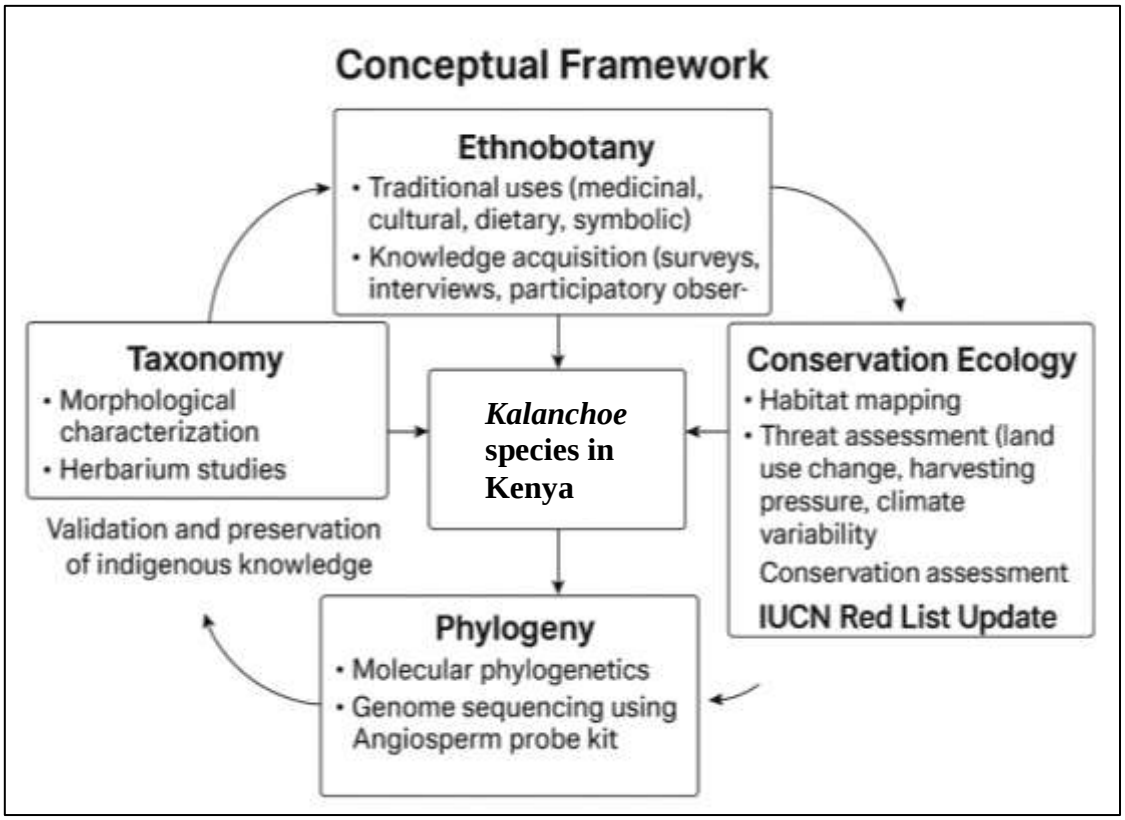

Figure 1.1. The Conceptual Framework of the Study (obser--observation)

Systematics deals with classification and organisation of living organisms based on their relationships, diversity and evolutionary history, it deals with both taxonomy and phylogeny. Taxonomy, the science of classification, organises plants based on their characteristics, aiding in identification, conservation, and sustainable utilisation (Lokare and Pandya, 2024; Antonelli *et al*., 2025). Phylogeny examines the evolutionary history and genetic relationship among plant species, providing insights into their adaptation and diversification (Morlon *et al*., 2024). Ethnobotany explores the relationship between people and plants, particularly the traditional knowledge surrounding their use for medicine, food, and cultural practices (Leonti *et al*., 2024; Dean, 2024). Conservation

focuses on protecting and sustainable use and management of plant species and their habitats to maintain ecological balance and sustain biodiversity for future generations (Singh, 2024; Kunhikannan *et al*., 2025; Nayak *et al*., 2025). Together, these disciplines support biodiversity conservation, validate indigenous knowledge, and enhance scientific understanding of plant diversity (Alrhmoun *et al*., 2025). Ethnobotanical research informs conservation priorities by identifying culturally significant species at risk while taxonomic and phylogenetic insights improve their identification, aiding in conservation planning.

Integrating these disciplines enhances biodiversity conservation and sustainable utilisation strategies for *Kalanchoe* species. Studies on *Kalanchoe* ecology and conservation status are essential for sustainable utilisation. Molecular phylogenetics, coupled with ecological mapping, can provide insights into species distribution under climate variability (Guisan *et al*., 2017). Additionally, ethnobotanical surveys should document traditional knowledge before it is lost due to cultural shifts. Conservation initiatives should integrate community participation to enhance species conservation efforts (Ngumbau *et al*., 2020).

CHAPTER TWO

LITERATURE REVIEW

This section provides an overview of the interdisciplinary approach to *Kalanchoe*'s biology, focusing on its morphology, Physiology, reproduction, taxonomy, distribution, molecular application of universal probe set in plant systematics and phylogeny and species complexes as well as chromosome numbers, ethnobotany, bioactive compounds and conservation. The review highlights key findings and identifies research gaps, offering insights into the diverse applications and challenges associated with *Kalanchoe* species.

2.1 Morphology and Taxonomy of *Kalanchoe* species

Morphologically, *Kalanchoe* species are predominantly perennial (rarely annual) terrestrial (occasionally epiphytic) succulent plants, well-adapted to arid and semi-arid climates due to their high water-storage capacity in specialized tissues and the unique CAM photosynthetic pathway (Kahram *et al*., 2022; Eggli and Nyffeler, 2023). Typically, *Kalanchoe* species are herbaceous or sub-shrub plants with fibrous root systems, reaching heights of 1 to 1.5 metres particularly during the flowering stage (Wickens, 1987; Agnew, 2013). Their succulent leaves are either petiolate or sessile and are generally arranged in opposite or opposite-decussate patterns (Plate 2.1). They exhibit diverse morphological traits—observable structural characteristics of plant form—,including oval to lanceolate leaf shapes with crenate, serrate or dentate margins, typically measuring 10 to 20 cm in length, with variable widths (Smith *et al*., 2019; Smith, 2022; Tolulope, 2023) (Plate 2.1, Figure 2.1). Leaf surfaces may be glabrous or covered with trichomes of varying size,

density and structure that enhance water retention and deter herbivore (Weryszko-Chmielewska, 2005; Hegazy, 2015; Olutayo *et al*., 2024). Plate 2.1 illustrates *K. marmorata* in cultivation and in the wild while Figure 2.1 shows morphological characters that were examined on *Kalanchoe* specimens.

Plate 2.1. *Kalanchoe marmorata* A. Cultivated B. Wild (Photo credits: C. Bjorå (A), G. Evusa (B))

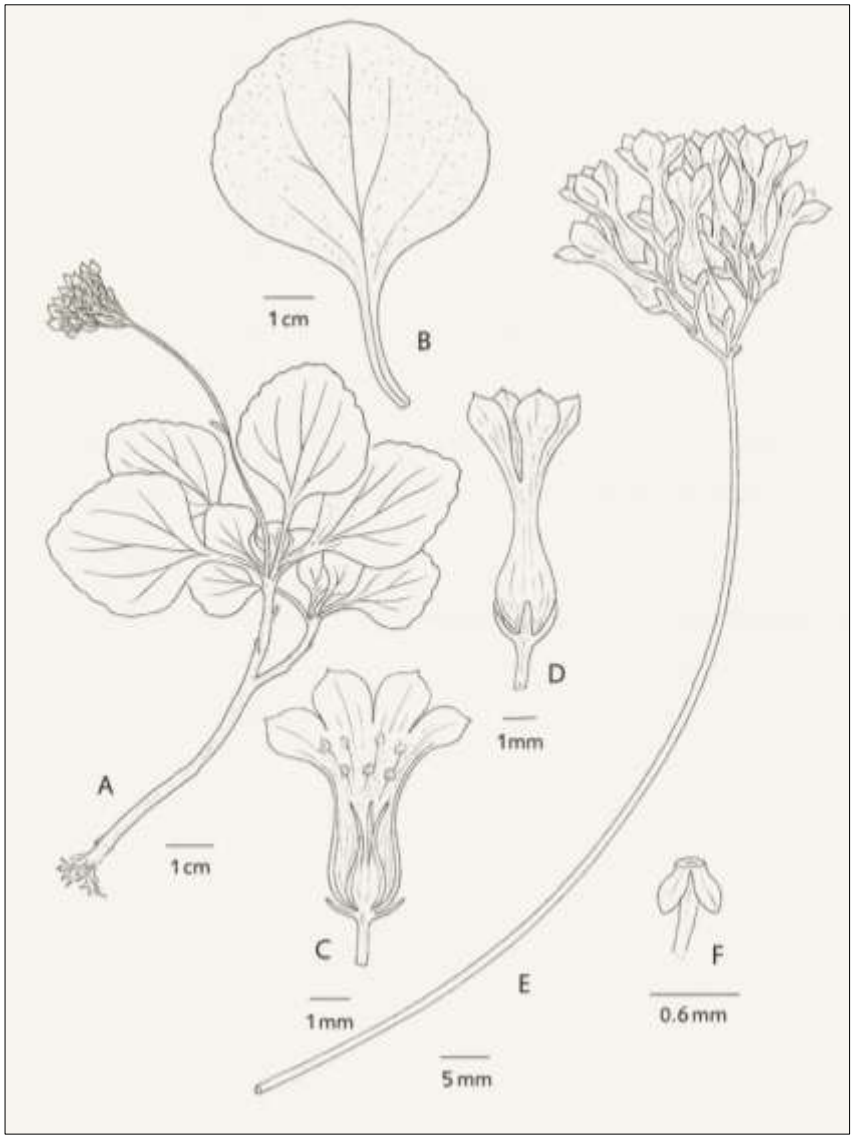

Figure 2.1. Illustrations Showing Morphological Characters that Were Examined on *Kalanchoe* Specimens A. Habit of the Plant **B.** Basal Leaf Structures (apex, margin, blade, petiole, attachment on stem) **C-D.** Dissected Flower Showing Reproductive Structures; Androecium (filaments (two sets), Anthers and Gynoecium (style and ovary) **E.** Inflorescence With Flowers **F.** Seed With Appendages. (Adapted from Illustration by Klein-Callm for *K. darainensis* D.-P. Klein and Callm. From Madagascar).

Kalanchoe species exhibit terminal inflorescences, with axillary flowers being rare. The inflorescences consist of flowers, typically up to 5 cm long, exhibiting a striking range of colours such as red, yellow, pink, and orange, attracting pollinators including bees, butterflies, and hummingbirds (Akulova-Barlow, 2009; Mackenzie *et al*., 2018; Smith *et al*., 2019). Their floral structures vary among species, forming corymbose, cymose, or paniculate arrangements, depending on environmental conditions and genetic factors (Mackenzie *et al*., 2018; Tolulope, 2023). The flowers are pedicellate, either erect or pendant, and display vibrant hues (Smith *et al*., 2019). Each flower is hermaphroditic, comprising four distinct petals, eight stamens arranged in two levels—four positioned lower and four higher—and four carpels (Baldwin, 1938; Wickens, 1987; Kahraman *et al*., 2022). Fruits are membranous, releasing numerous minute ellipsoid seeds adapted for wind dispersal. Anatomically, the stems feature an epidermal layer with a resin-impregnated cuticle, reducing transpiration, while the underlying parenchyma cells store water, further enhancing drought tolerance (Assis de Andrade, 2023).

The taxonomy of the genus *Kalanchoe* is notably complex and is characterized by taxonomic ambiguity—an uncertainty in clearly distinguishing and delimiting species due to overlapping or insufficient diagnostic traits**.** As Wickens (1987) noted, the distinctions between taxa within the genus are often less clear-cut than suggested by available identification keys. This ambiguity is further reflected in the overlapping morphological features commonly used for species differentiation, including corolla tube length, flower color, and vegetative characteristics (Wickens, 1987). For example, species like *K.*

marmorata, K. aubrevillei, K. mitejea, K. nyikae, K. boranae and *K. prittwitzii* all exhibit significantly overlapping corolla-tube lengths ranging between 15–120 mm. Similarly, species such as *K. glaucescens, K. densiflora,* and *K. crenata* share shorter corolla-tube lengths (4.5–12 mm), yet some of these ranges still overlap with the longer categories, making precise identification difficult. Additionally, floral color variation, such as the pink to bright red corolla in *K. ballyi* and yellow to pale pink in *K. lanceolata*, adds another layer of complexity. These overlaps in key diagnostic characters blur the boundaries among species, showing the limitations of using morphology alone for taxonomic resolution in the genus.

Although Wickens (1987) provided one of the earliest and most comprehensive accounts of *Kalanchoe* species in the *FTEA*, his treatment was largely descriptive and relied on observational macromorphological traits such as leaf arrangement, inflorescence structure and floral coloration. The study did not incorporate quantitative morphometric analyses or statistical validation of morphological variation. Several East African *Kalanchoe* taxa remain poorly delineated, with unresolved intraspecific variability and uncertain diagnostic boundaries.

The taxonomic difficulty within *K. lateritia* and *K. nyikae* complexes, results from ovelapping vegetative and floral traits obscuring varietal and subspecific distinctions. For instance, *K. lateritia* var. *prostrata* and *K. lateritia* var. *lateritia* differ in stem posture and hairiness, yet they share overlapping corolla-tube lengths (8.5–12 mm), while *K. lateritia* var. *pseudolateritia* displays a slightly longer tube (approximately 14 mm). Similarly, *K.*

nyikae subsp. *nyikae* and *K. nyikae* subsp. *auriculata* differ in leaf attachment and margin traits, yet again, these characters' exhibit degrees of overlap that hinder conclusive differentiation. In some cases, even characters like glandular pubescence, stem orientation, and leaf shape fail to provide consistent diagnostic utility across all specimens. These challenges indicate that morphological analysis alone may not suffice to resolve the taxonomic relationships within *Kalanchoe*. Therefore, integrating molecular data with traditional morphological approaches holds promise for refining species boundaries and provides a more robust taxonomic framework, an approach this study sought to undertake.

Several studies have examined morphological diversity—the extent of variation in physical forms, structures, and observable traits either within a species or across different species—of *Kalanchoe*, highlighting the wide range of adaptations exhibited in the genus (e.g., Wickens, 1987). Understanding this diversity relies first on morphological characterization, which refers to the systematic description, observation, and measurement of key physical traits that define each taxon. This process provides the foundational data needed to distinguish closely related species and to interpret their ecological and evolutionary relationships. In *Kalanchoe*, morphological characterization typically includes documenting traits such as leaf shape, size, colour, margin type, inflorescence arrangement, and stem morphology.

For instance, a study conducted in Bangladesh examined five species, including *K. gastonis-bonnieri* and *K. delagoensis* Eckl. and Zeyh., based on macro morphological traits (Laskar *et al*., 2023). The researcher, found notable interspecific variations in leaf

arrangement, shape and floral morphology, which were effective in distinguishing among species; however, they also observed overlapping traits that limited the accuracy of identification when using morphology alone. Similarly, research in Nigeria focused on the vegetative morphology of selected species from the subgenera *Kalanchoe* and *Bryophyllum*, analysing leaf shape, stem texture, and floral characteristics to identify distinguishing features (Tolulope *et al*., 2023). This study identified problems related to phenotypic plasticity and environmental influence on morphological traits, which complicated constistent species delimitation across ecological zones. Despite these challenges, the study of Tolulope *et al*. (2023) provided valuable insights into species differentiation, contributed to refining the taxonomic classification of *Kalanchoe*, thereby highlighting the importance of detailed morphological investigations in delineating species within the genus.

In addition to taxonomic differentiation, phenotypic plasticity−the ability of an organism to exhibit variation in observable traits in response to environmental conditions has also been investigated in *Kalanchoe*, particularly in relation to how changing habitats influence morphological expression (Zhang *et al*., 2024). Research has demonstrated that *Kalanchoe* species exhibit significant plasticity in vegetative growth when subjected to varying environmental conditions such as light intensity and water availability (Kluge *et al*., 2001; Smith, 2023). This plasticity allows species to thrive in diverse habitats, reflecting their adaptive strategies. However, the trait has greatly contributed to the complexity in the

taxonomy of *Kalanchoe* resulting from overlap in morphological characters within the existing species complexes across different *Kalanchoe* species.

Previous studies (Laskar *et al*., 2023; Tolulope *et al*., 2023; Rodewald *et al*., 2025) have made notable contributions to the morphological understanding of the genus. Some have conducted comparative analyses across species or populations to reveal phenotypic variation and adaptive differentiation while others have examined how environmental factors such as light intensity, water availability and soil type, influence morphological expression. Additionally, recent trends have seen the integration of morphological data with molecular tools—a combined approach that strengthens species delimitation and clarifies phylogenetic relationships within the genus.

Despite these advancements, there remains substantial research gaps. Many existing studies rely heavily on qualitative morphological descriptions rather than rigorous quantitative morphometric analyses, which can provide satisfactory robust discrimination among species. Moreover, intraspecific variation—differences within a species due to environmental or genetic factors—has not been extensively explored. As a result, the full potential of morphometric techniques for refining the taxonomy of *Kalanchoe* is yet to be realised. Further research incooperating integrative taxonomic approaches combining morphometric and molecular phylogenetics data, was essential to resolve existing ambiguities and enhance our understanding of species boundaries and evolutionary processes within the genus.

While morphological characterization remains a primary tool for species identification, integrating morphological data with molecular techniques has enhanced diversity assessments. A study on five *Kalanchoe* genotypes combined morphological parameters, including plant height, number of inflorescences, and floral traits, with molecular markers such as RAPD, ISSR, and SCoT-PCR (Al-Khayri *et al*., 2022). The findings revealed distinct morphological and genetic profiles, facilitating breeding and conservation efforts. However, the combined use of morphological and molecular approaches remains insufficiently explored for many *Kalanchoe* species.

Despite these advancements, several research gaps persist in the morphological characterization of *Kalanchoe*. There is a lack of comprehensive morphological databases that encompass a broader range of species, limiting accurate taxonomic classification. Addressing these gaps enhances understanding of *Kalanchoe*'s morphological diversity, supporting conservation efforts, taxonomic clarity, and breeding programs. The integration of cutting-edge molecular techniques and advanced genomic tools, such as genome sequencing, provides deeper insights into the genetic basis of morphological variations in *Kalanchoe* and helps bridge existing knowledge gaps in the taxonomy and characterization of *Kalanchoe*.

2.2 Species Complexes

A species complex consists of taxa (species, subspecies and varieties) whose taxonomic boundaries are not well defined and in the genus *Kalanchoe* several species complexes such as *K. lateritia* as well as *K. nyikae* exist. As noted by Raadts (1977) and Wickens

(1987) the relationship among most of the species still needs refinement. Raadts (1989) pointed out the intimacy in the relationship among taxa in Kalanchoideae Berg. making it difficult to separate its members using morphological characters and with the polyploidy as well as hybridization, it is even more difficult.

The genus *Kalanchoe* exhibits significant morphological diversity, particularly in floral characteristics such as corolla tube length and color. For instance, species like *K. marmorata*, *K. aubrevillei*, *K. mitejea*, *K. nyikae*, *K. boranae*, and *K. prittwitzii* have notably long corolla tubes, whereas *K. glaucescens*, *K. densiflora*, and *K. crenata* possess shorter corolla tubes (Wickens, 1987). This variation is further exemplified by *K. ballyi*, which displays pink to bright red corolla coloration on the upper part, contrasting with *K. lanceolata*, which exhibits yellow to pale pink colours above (Wickens, 1987). Such distinctions in corolla morphology are crucial for species identification and understanding reproductive strategies within the genus (Raadts, 1977).

In addition to floral traits, vegetative characteristics such as stem posture, leaf pubescence, and inflorescence hairiness contribute to the taxonomic complexity within *Kalanchoe* (Descoings, 2003). For example, *K. lateritia* var. *prostrata* is differentiated from *K. obtusa* based on stem orientation and inflorescence hair types, though overlaps in glandular hair presence can blur these distinctions (Wickens, 1987). Similarly, within the *K. lateritia* complex, varieties are primarily distinguished by a combination of vegetative and floral features, including stem posture, leaf shape, and corolla tube length (Wickens, 1987). However, these morphological markers sometimes overlap, making precise identification

challenging. To address these ambiguities, integrating molecular data with traditional morphological analyses is essential for clarifying phylogenetic relationships and ensuring accurate taxonomic classifications within the genus (Gehrig *et al*., 2001).

Taxonomic, cytological, embryological, anatomical and other informative studies done in *Kalanchoe* (Raadts, 1984, 1989) did not fully resolve the relationships within some of the unresolved species complexes viz., *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae*; *K. lateritia* var. *lateritia, K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* among others prompting this study to apply molecular in addition to morphometric approaches to further clarify the relationships.

2.3 Physiology of *Kalanchoe*

Most *Kalanchoe* species exhibit Crassulacean Acid Metabolism (CAM), a specialized photosynthetic pathway that enhances water-use efficiency in arid and drought-prone environments. Crassulacean Acid Metabolism is characterized by nocturnal stomatal opening, which reduces transpirational water loss by allowing gas exchange when evapotranspiration rates are lowest (Yang *et al*., 2017; Nwokeocha, 2023). During the night, absorbed Carbon (IV) oxide is fixed by phosphoenolpyruvate carboxylase (PEPC) and stored in vacuoles as malic acid. In daylight, stomata close, malic acid is decarboxylated, and the released Carbon (IV) oxide is used in the Calvin cycle for carbohydrate synthesis (Brulfert *et al*., 2019; Qiu *et al*., 2023).

Kalanchoe has historically played a central role in CAM research because it was one of the first genera in which the diurnal acid fluctuation characteristic of CAM was described (Cushman and Bohnert, 1997). Several species, particularly *K. daigremontiana* and *K. pinnata*, are widely used as model systems for studying CAM regulation, diel metabolic compartmentation, and the molecular basis of drought adaptation (Yang *et al*., 2017).

Physiologically, CAM in *Kalanchoe* is associated with succulent leaf morphology, which provides large vacuolar storage space for organic acids, and with thick cuticles, reduced surface-area-to-volume ratios, and specialized water-conserving anatomical traits (Eggli and Nyffeler, 2023). The flexibility of CAM—often expressed as facultative or inducible CAM—allows some *Kalanchoe* species to shift between C_3 and CAM metabolism depending on environmental stress, enhancing survival under fluctuating moisture conditions (Winter and Holtum, 2014). The evolution of CAM in *Kalanchoe* is closely linked to their native habitats, many of which are characterized by seasonal drought, high temperatures, and limited soil moisture. Crassulacean Acid Metabolism provides a strong ecological advantage, enabling colonization of rocky outcrops, inselbergs, and shallow-soil environments where water availability is unpredictable (Eggli and Nyffeler, 2023). This unique physiological adaptation contributes to the ecological success, resilience, and wide distribution of *Kalanchoe* species.

Fucultative species such as *K. blossfeldiana* exist in the genus *Kalanchoe* (Kang *et al*., 2019; Winter, 2019). *Kalanchoe* displays strong photoperiodic sensitivity: Kang *et al*. (2019) showed that the quality and intensity of night-interruption light can promote or

delay floral induction and reshape vegetative morphogenesis, indicating light-mediated control over reproductive timing and plant architecture. Coupled with this developmental plasticity, *Kalanchoe*'s facultative CAM capacity allows it to switch carbon-assimilation modes in response to environmental stress, enhancing stomatal control and water-use efficiency as described by Winter (2019), which links photoperiod-driven phenology to flexible ecophysiological resilience.

2.4 Reproduction of *Kalanchoe*

Some species of *Kalanchoe* exhibit a unique form of vegetative reproduction through viviparous plantlets along the leaf margins, facilitating rapid colonization survival in suitable habitats (Gehrig *et al*., 2001; Parihar, 2022; Zhang *et al*., 2024). A key reproductive feature of *Kalanchoe* flowers is protandry, where the male reproductive organs (stamens) mature before the female organs (carpels), reducing the likelihood of self-pollination and promoting cross-pollination (Mackenzie *et al*., 2018; Smith *et al*., 2022). The lower anthers dehisce first, releasing pollen, while the stigma remains immature. As the flower progresses in development, the style elongates, and stigmatic exudates appear, facilitating receptivity to pollen (Kuligowska *et al*., 2015; Kahraman *et al*., 2022). This mechanism increases genetic diversity, a crucial factor in the adaptability of *Kalanchoe* species to diverse environmental conditions (Guerra-Garcia *et al*., 2015). However, in the absence of cross-pollination, self-pollination may occur through delayed interaction between the stigma and the remaining pollen from the stamens (Gehrig *et al*., 2001).

2.5 Distribution of *Kalanchoe*

Kalanchoe is the third largest genus in the family Crassulaceae, with species native to—and introduced in—tropical and subtropical regions of Africa, the Americas, Asia, and Australia as shown in Figure 2.2 (POWO, 2025). Many of the introduced species were deliberately brought into cultivation by horticulturists and plant traders because of their ornamental appeal (Vargas *et al*., 2022). In Ecuador, for example, the presence of wild *Kalanchoe* taxa correlates strongly with cultivated garden stocks, suggesting that the invasion pathway is primarily through escape from ornamental trade (Vargas *et al*., 2022). In addition, some species such as *K. pinnata* and *K. daigremontiana* have been spread due to their use in traditional medicine, where they are valued for anti-inflammatory, wound-healing, and other pharmacological properties (Milad *et al*., 2013). The capacity for vegetative propagation (via leaf bulbils) also increases their potential to naturalize in new areas (Smith, 2025). The global distribution of *Kalanchoe* is displayed in Figure 2.2.

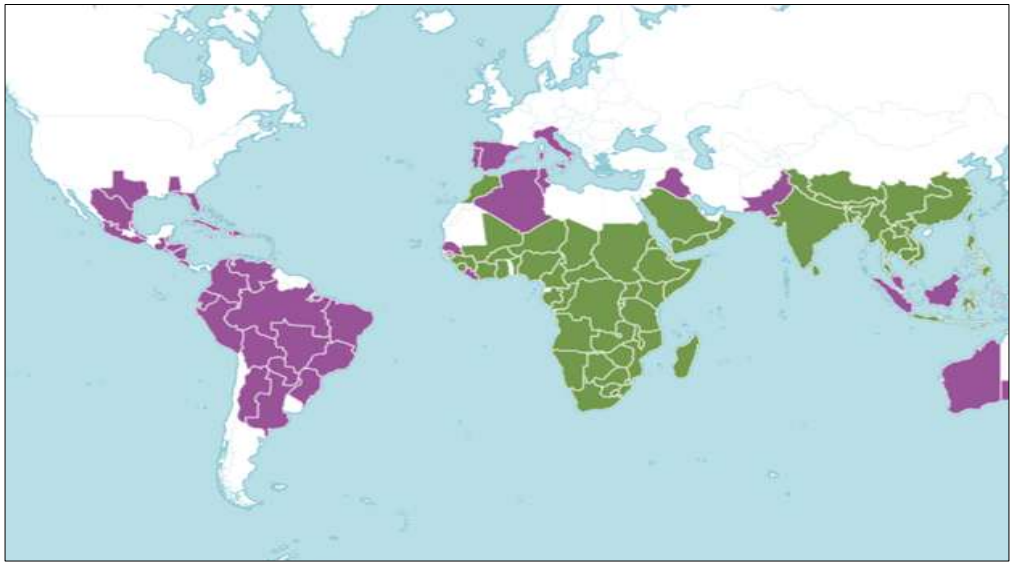

Figure 2.2. A Map Showing the Global Distribution of *Kalanchoe*, Both Native and Introduced (POWO, 2025). Native Introduced.

In East Africa, *Kalanchoe* species occur as leaf-succulent epiphytes, herbs, or shrubs, occupying a wide ecological spectrum that includes damp stream banks, muddy and seasonally waterlogged areas, shaded shallow soils, tree trunks in moist forests, upland grasslands, and rocky or disturbed outcrops. Their distribution spans approximately 450–4,250 m in elevation, corresponding to mean annual temperature regimes of 8–28°C—with lower elevations experiencing warm conditions (20–28°C) and high-altitude habitats (>3,000 m) characterized by much cooler temperatures (as low as 8–12°C). This ecological breadth highlights the genus' adaptability across semi-arid, sub-humid, and montane environments of the region (Wickens, 1987; Agnew, 2013; Smith *et al*., 2022).

While some taxa are naturalised, many are cultivated in green houses and gardens (Smith, 2023; POWO, 2025). In Kenya and across East Africa, *Kalanchoe* species are both

cultivated and naturalised. While several taxa have established self-sustaining wild populations, many others remain primarily cultivated in greenhouses, home gardens, ornamental landscapes, and botanical collections**.** Their popularity is linked to their drought tolerance, ease of propagation, and ornamental value. As a result, horticultural cultivation coexists with naturalised occurrences across diverse habitats in the region (Wickens, 1987; Smith, 2023; POWO, 2025).

Widely cultivated for their ornamental value and medicinal value, *Kalanchoe* species play an essential ecological role (Sharmin *et al*., 2016). Their fibrous root systems contribute to soil stability, mitigating erosion on steep slopes (Raadts, 1977). Additionally, *Kalanchoe* species exhibit high water retention capabilities while their wax-covered stems enhance fire resistance, aiding vegetation re-establishment after wildfires (Smith *et al*., 2019).

2.6 *Kalanchoe* in Kenya

Kalanchoe in Kenya are distributed across multiple habitats, including semi-arid bushlands, rocky outcrops, forest margins and the Aberdare Range shaped by the countries varied climate, topography and geological history (Beentje, 1994; Wickens, 1987; Agnew, 2013). Each of these regions harbours distinct vegetation types, with varying levels of species endemism. Some species, such as *K. lanceolata*, thrive in dry savanna, while others, such as *K. marmorata*, are found in montane forests and rocky areas (Smith *et al*., 2022). Kenya is divided into seven (K1–K7) flora regions (localities) based on earlier (district) administrative boundaries (currently referred to as counties). The Flora regions indicate plant distribution regions in *Flora of Tropical East Africa*. *Kalanchoe* adapts to

different climatic conditions in all the seven flora regions. Kenya's flora is shaped by ecological regions, altitude and climate, with distinct plant communities characterizing different parts of the country. The coastal region, including counties such as Mombasa, Kilifi, and Kwale, is dominated by mangroves, coastal forests and dune vegetation. The lowland arid and semi-arid regions, covering counties like Turkana, Garissa, and Mandera, support drought-tolerant shrubs and savanna grasses. Central highland and mid-altitude areas, including Nyeri, Kiambu, and Meru, are characterized by montane forests, woodlands, and agricultural landscapes. The high-altitude regions of counties such as Mount Kenya (Kirinyaga, Laikipia) and the Aberdares (Nyandarua, Nakuru) host Afro-alpine vegetation and bamboo forests.

Altitude strongly influences species distribution, with lowlands favoring drought-resistant taxa and higher elevations supporting montane and alpine flora. For detailed explanations of Kenya's flora regions and altitudinal patterns, see Zhou *et al*. (2017) and Mutie *et al*. (2023). For comprehensive overviews of Kenya's floral diversity, consult White (1983) and Beentje (1994).

The Flora regions include; K1 – The Northern Frontier Province in the North, K2 – The Turkana Province in the North West, K3 – Rift Valley Province in the West, K4 – The Central Province in the Center, K5 – The Nyanza Province in the South West, K6 – The Maasai Province in the South and K7 – The Coast Province along the Coast (Figure 2.3). The adaptability of *Kalanchoe* to different ecological conditions underscores its resilience and potential for further studies on its environmental tolerances. Although the Flora of

Kenya is currently under revision, only two plant families—Orchidaceae Juss. and Rubiaceae Juss.—have been completed, leaving families such as Crassulaceae and many others yet to be revised, thereby highlighting a significant gap in the botanical documentation and taxonomic understanding of the country's flora.

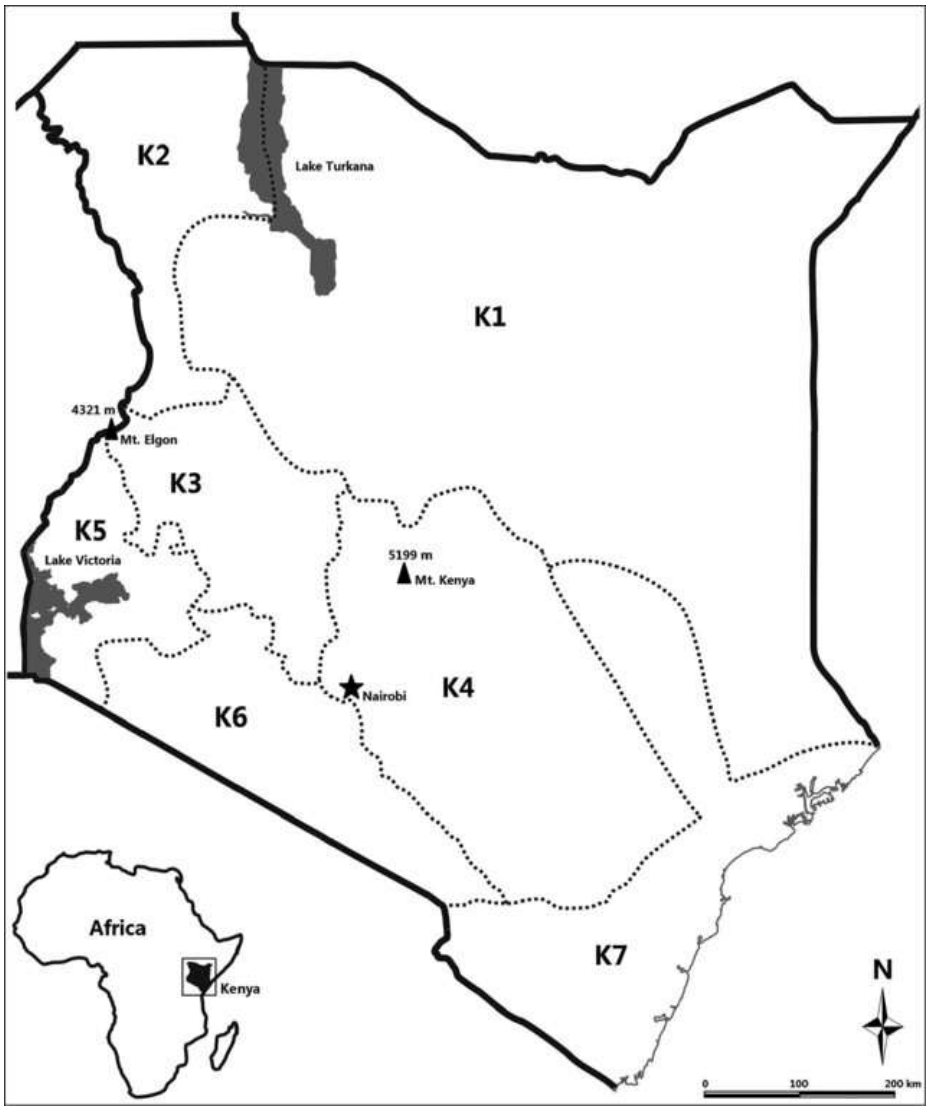

Figure 2.3. Map of Kenya Showing A. Flora regions (K1-K7) According to the *Flora of Tropical East Africa* (*FTEA* editors 1952-2012).

2.7 Systematics of Crassulaceae

Crassulaceae is the largest family of succulent plants in the Order Saxifragales Bercht. and J. Presl. (Gontcharova and Gontcharov, 2009; Chang *et al*., 2021). The family includes 1500 species of perennial herbs and delicate stemmed miniature shrubs or trees in about 39 genera (Smith *et al*., 2017; POWO, 2025). The concept of monophyly in the family is problematic. Morphology-based grouping has resulted in taxonomic complexity within and among its genera (Soltis *et al*., 2013: Karakish *et al*., 2016; Zlatković *et al*., 2019). This taxonomic complexity is observed in the subfamily Kalanchoideae, particularly in the genus *Kalanchoe* and is often attributed to extensive variability in flower morphology, polyploidy, the huge number of species and geographical diversity of the genera and delimitations that are mainly based on living or cured materials (Gontcharova and Gontcharov, 2009; Chernetskyy, 2011; Smith and Figueiredo, 2018). In the *FTEA*, Wickens (1987) characterised Crassulaceae into eight genera viz., *Crassula* L., *Echeveria* DC., *Sedum* L., *Aeonium* Webb. and Berthel., *Bryophyllum*, *Kalanchoe*, *Cotyledon* Tourn ex L. and *Umbilicus* DC. based mainly on morphology. Seven of the eight genera identified by Wickens (1987) were also upheld by Agnew (2013) in his works on the flora of the highlands of Kenya. Their investigations coincided on the position and discretion of the genera and some species.

Taxonomic complexity in the family Crassulaceae obscures its study at many levels (Gontcharova *et al*., 2009; Salim *et al*., 2019). The most cited infra-familial classification of Crassulaceae was proposed by Berger (1930) based on morphology and geographical

dispersion of the genera. Molecular tools revealed a lack of monophyly in five subfamilies of the family (Berger, 1930) contrary to what Uhl (1963) had postulated (Van Ham and t' Hart, 1998). Mort *et al*. (2001) findings on matK sequence data concurred with those from cpDNA restriction recognition site investigations (Van Ham and t' Hart, 1998) revealing *Kalanchoe* as second-branching pedigree in Crassulaceae. The equivocalness in the phylogeny and taxonomy of subfamilies and genera in Crassulaceae remains a contentious issue to date (Han *et al*., 2024; Rodewald *et al*., 2025). This necessitates a detailed exploration into phylogeny and taxonomic relationships within the family (Gallo, 2017; Giuliani *et al*., 2018; Liu *et al*., 2023).

2.8 Systematics of *Kalanchoe*

The genus *Kalanchoe* (Crassulaceae: Saxifragales) comprises a diverse group of succulent angiosperms chiefly distributed in Madagascar and sub-Saharan Africa. The genus is accepted and has 175 species and eight synonyms (POWO, 2025). *Kalanchoe* was first published in 1763 by the French naturalist Michel Adanson in his work *Familles des Plantes*. Adanson described the genus after observing that while the name *Kalanchoë* had not been previously used, a plant belonging to this genus had been described and illustrated by Rumphius (1750) under the name of *Tsjaccarbebe*—a non-linnean designation for *K. laciniata* (Chernetskyy, 2011). He wrote the name *Kalanchoe* on the herbarium sheet containing *K. laciniata* (synonym *Cotyledon laciniata* L.). Adanson also proposed that the species *K. laciniata*, later classified as this taxon, was first discovered and described in China as its native region (Baldwin, 1938). The name *Kalanchoë* is believed to have been

derived from the Chinese term "*Kalan Chauhuy*" meaning "that which falls and grows", referring to the plant's ability to reproduce through leaf plantlets (Boiteau and Allorge-Boiteau, 1995; Smith *et al*., 2019). Additionally, India has been suggested as another possible source of the name, derived from '*Kalanka chaya*' meaning 'rust gloss' in reference to the bright and showy leaves of *K. laciniata* in India (Eggli, 2003; Smith *et al*., 2019). Since then the classification of the genus *Kalanchoe* has undergone multiple revisions, with ongoing debates over the validity of segregate genera such as *Bryophyllum* and *Kitchingia* (Hamet, 1907; Perrier de la Bâthie, 1928 in Chernetskyy, 2011; Mackenzie *et al*., 2018).

Historically the genus delimitation and infrageneric classification have been contentious—*Bryophyllum* and *Kitchingia* have been variably treated as separate genera or as subgeneric units—but modern treatments (Descoings and Lavranos, 2006; Smith and Figueiredo 2018) favour a broadly circumscribed *Kalanchoe*. Hamet (1907) in his publication of the first monograph of *Kalanchoe*, suggested the merging of *Kalanchoe*, *Kitchingia* and *Bryophyllum* into a single genus, *Kalanchoe*. Perrier de la Bathie (1928) concurred with this view. However, Mannoni and Boiteau (1947) split the genus into the three sections—*Kalanchoe* (Eukalanchoë Boit. *et* Mann.), *Bryophyllum* and *Kitchingia* (Bak.) Boit. et Mann. which have hence been treated by some authors as a single genus *Kalanchoe* or independent genera or separate sub-genera under genus *Kalanchoe* (Smith *et al*., 2021; Tian *et al*., 2021; Rodewald *et al*., 2025). Decary (1962) and Hamet and Marnier-Lapostolle (1964) published papers on *Kalanchoe* but they were hardly informative as they

contained scanty taxonomic information (Lauzak-Marchal, 1974). Molecular phylogenetic work (ITS-based: Gehrig *et al*. 2001) supported inclusion of former *Bryophyllum* taxa within *Kalanchoe*. The phylogenetic relationship investigated among *Kalanchoe* taxa by Gehrig *et al*. (2001) included only 5 species from Kenya (See Figure 2.4.). The figure presents a phylogenetic tree depicting the evolutionary relationships among different species of *Kalanchoe*, categorizing them into Malagasy and other African groups. The Roman-numerals represent subsections of *Kalanchoe.*

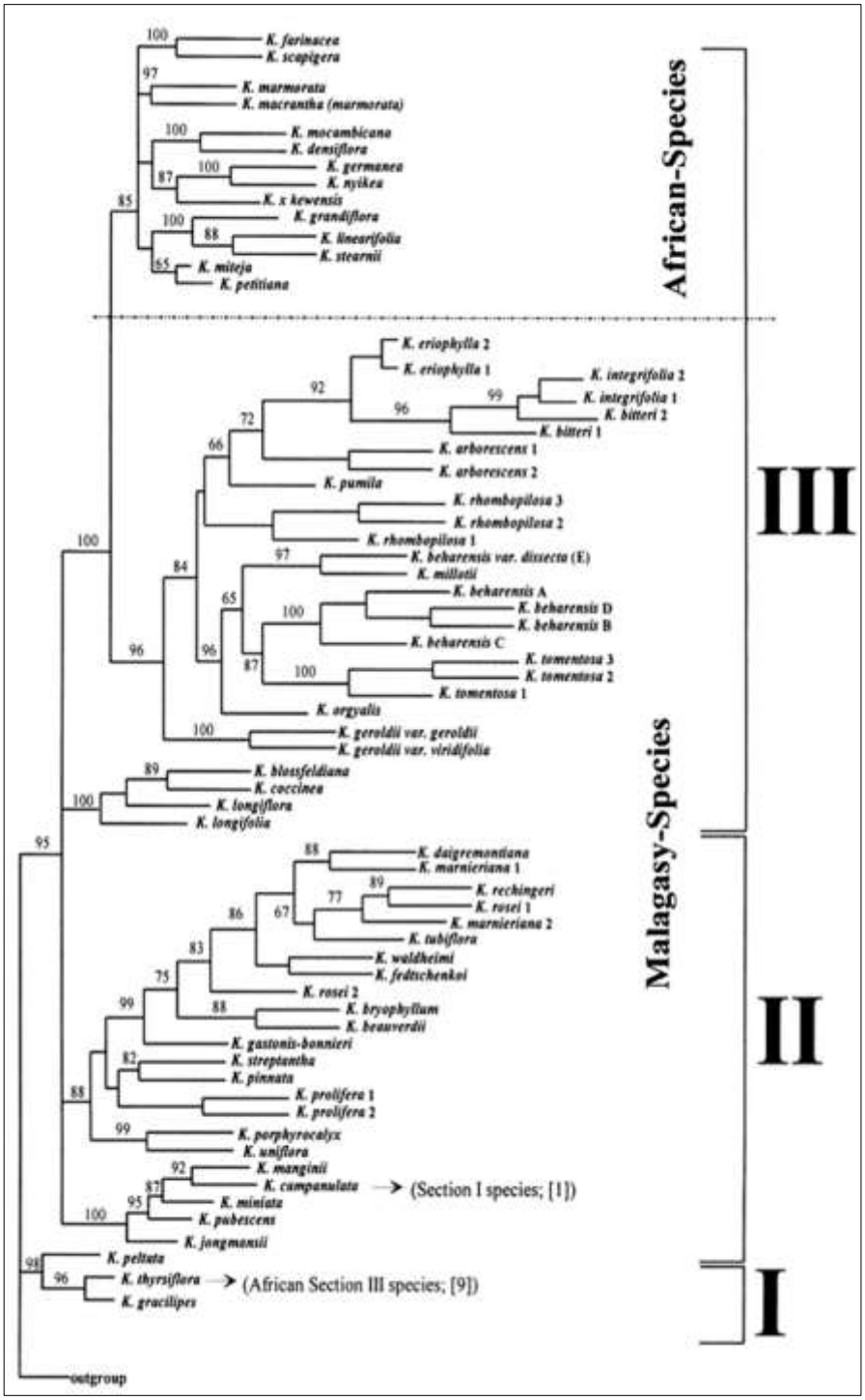

Figure 2.4. Cladogram of Species of the Genus Sampled From Madagascar Subsections I (*Kitchingia*), II (*Bryophyllum*) and Madagascar and a few other African countries subsections III (*Kalanchoe*) (Gehrig *et al*., 2001).

From Figure 2.4, the other African *Kalanchoe* species cluster together in a distinct clade, separate from the Malagasy species, suggesting a clear phylogenetic divergence. The presence of well-supported bootstrap values indicates strong genetic differentiation within African sections, reinforcing their evolutionary uniqueness. Phylogenetic studies suggest distinct Malagasy and other African countries clades within *Kalanchoe* (Gehrig *et al*., 2001). The investigation utilized sequences from the internal transcribed spacer (ITS) regions of nuclear ribosomal DNA revealing that *Kalanchoe* forms a monophyletic group, further dividing it into three main clusters aligning with traditional taxonomic sections. This study also suggested Madagascar as the center of phylogenetic radiation for the genus, with subsequent dispersal to continental Africa (Gehrig *et al*., 2001).

More recent research employing phylogenomic double-digest restriction-site associated DNA sequencing (ddRADseq) has provided a refined phylogenetic framework for *Kalanchoe*, identifying four well-supported clades, partially corresponding to existing subgeneric classifications (Rodewald *et al*., 2025) (See Figure 2.5). Notably, it indicated a Malagasy origin for the genus, followed by dispersal events to mainland Africa, the Arabian Peninsula, and Southeast Asia. The study also inferred a single evolutionary origin for the formation of bulbils on leaf margins within a specific clade of *K*. subg. *Bryophyllum*, a trait that has attracted other investigations (Tian *et al*., 2021; Parihar, 2022).

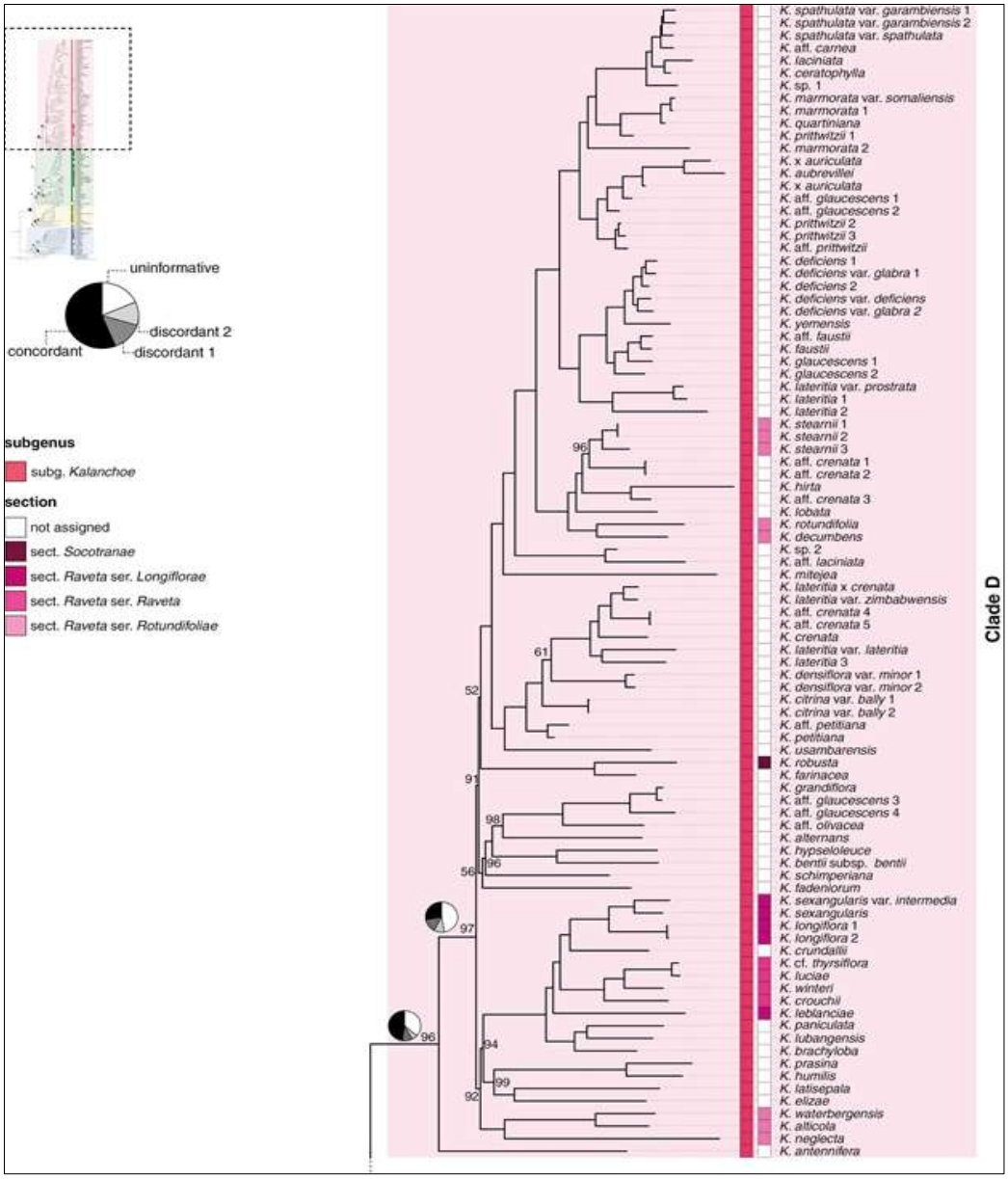

Figure 2.5. Cladogram of Species of the Genus Displaying Maximum Likelihood Phylogeny of *Kalanchoe* s.l. (Sub-genus *Kalanchoe* (Clade D)) Inferred From the Concatenated Alignment of ddRADseq Loci. Colour Corresponds to the Four Sampled Clades. (Rodewald *et al*., 2025).

Comparative analyses of complete plastid genomes from five *Kalanchoe* species have further contributed to the understanding of the genus's evolutionary history, identifying numerous simple sequence repeats (SSRs) and long repeats, predominantly located in the inverted repeat regions (Tian *et al*., 2021). Additionally, highly divergent regions with single nucleotide polymorphisms (SNPs) and insertions or deletions (InDels) were discovered, offering potential markers for future phylogenetic studies. The analyses also revealed several genes under positive selection, which may have played roles in the adaptation of *Kalanchoe* species to arid environments. These molecular studies collectively provide a robust framework for the phylogenetic and taxonomic understanding of *Kalanchoe*, informing both evolutionary research and conservation strategies for this diverse genus. However, the placement of Kenyan *Kalanchoe* species within the *Kalanchoe* phylogeny remains incomplete. The current study focused on classification and phylogeny of the genus *Kalanchoe* in Kenya and their possible placement in *Kalanchoe* phylogeny using molecular data.

Kalanchoe exhibits extensive hybridization and a range of ploidy levels, including diploid, polyploid and aneuploid species, contributing to its adaptability and speciation (Kahraman *et al*., 2022). Many species within the genus display complex polyploid series, with chromosome numbers ranging from diploid to hexaploid (Baldwin, 1938; Boiteau and Allorge-Boiteau, 1995). Hybridization events, both natural and artificial, have led to morphological diversity and enhanced horticultural traits in commercial *Kalanchoe* cultivars (Smith *et al*., 2019). Furthermore, polyploidy influences secondary metabolite

production, potentially affecting the pharmacological properties of medicinal *Kalanchoe* species (Kołodziejczyk-Czepas and Stochmal, 2017). As a result, future research should investigate genetic diversity and hybridization patterns to optimize conservation and breeding programs.

2.9 Application of Universal Probe Set in Plant Systematics and Phylogeny

Target sequence capture using universal probe sets targeting conserved nuclear genes has become an essential tool for studying the genetics and evolution of Angiosperms (Johnson *et al*., 2019). This method involves the use of specific oligonucleotide probes that bind to conserved genomic regions, allowing for the selective enrichment and sequencing of target sequences. Such an approach significantly enhances the resolution of sequencing data, particularly for conserved nuclear genes, which are critical for understanding the evolutionary history, genetic diversity, and functional biology of plants. These universal probe sets are useful for both functional genomics and phylogenetics studies, as they provide a broad perspective on plant genetics and allow for the analysis of deep evolutionary relationships (Johnson *et al*., 2019). One key advantage of using these probes is their ability to capture sequences across a wide variety of plant species, facilitating large-scale comparative genomics and phylogenetic analysis (McKain *et al*., 2018).

By capturing and sequencing these genes across a wide range of species, researchers can reconstruct phylogenies and investigate the diversification patterns of plant lineages. Target sequence capture using universal probe set that targets sequencing of 353 conserved nuclear genes from Angiosperms, have been successfully used to investigate phylogenetic

relationships at different taxonomic levels (Johnson *et al*., 2018; Romeiro-Brito, 2022; Fonseca *et al*., 2023). The universal probe set together with family specific probes were used to investigate the phylogeny of the Gesneriaceae Rich. and Juss and Ochnaceae DC. families (Ogutcen *et al*., 2021; Shah *et al*., 2021), demonstrating that the method could resolve evolutionary relationships within different plant groups with remarkable precision. The molecular tools have been successfully used in taxonomic revisions and validation of plant species of medicinal importance (Simões *et al*., 2022; Wang *et al*., 2024). This molecular approach also facilitates the study of species that are difficult to analyze with more traditional markers, providing a more comprehensive view of evolutionary relationships across diverse plant groups (Wang *et al*., 2024). Furthermore, the conserved nature of the targeted genes makes them highly informative, as they reflect the shared genetic heritage of Angiosperms, offering insights into the broader evolutionary processes shaping the plant kingdom.

2.10 The Role of Molecular Studies in Solving Problems of Species Complexes in *Kalanchoe* and Related Genera

Molecular studies have played a crucial role in resolving taxonomic ambiguities within species complexes of *Kalanchoe* and related genera by providing insights into genetic divergence, evolutionary relationships and hybridization events. Traditional morphological classification often struggles to delineate species boundaries due to phenotypic plasticity, polyploidy, and frequent hybridization (Gehrig, 2001; Kahraman *et al*., 2022; Zhang *et al*., 2024). Molecular markers such as chloroplast DNA sequences, nuclear ribosomal ITS

regions, and microsatellites have been instrumental in clarifying species identities and phylogenetic relationships (Zaman *et al*., 2025). For instance, phylogenetic analyses using plastid and nuclear markers have helped distinguish cryptic species and infer evolutionary histories in *Kalanchoe* and its close relatives (Tian *et al*., 2021; Ding *et al*., 2022; Rodewald *et al*., 2025). Furthermore, DNA barcoding techniques have facilitated species identification and conservation efforts by detecting genetic variations that are not apparent in morphological studies (Han *et al*., 2024; Sidingin, 2024). These molecular approaches contribute to biodiversity assessments, ecological studies, and the effective conservation of *Kalanchoe* species, particularly in regions like Kenya where species diversity is high and taxonomic uncertainties persist.

Beyond taxonomy, molecular studies have also been instrumental in understanding the evolutionary mechanisms driving speciation and adaptation within *Kalanchoe* and related genera. Genome-wide analyses and next-generation sequencing (NGS) technologies have revealed patterns of genetic differentiation, introgression, and adaptive evolution in response to environmental pressures (Hong *et al*., 2023; Hu *et al*., 2024). For instance, research on the genetic basis of Crassulacean Acid Metabolism (CAM) in *Kalanchoe* has provided insights into how species within the genus adapt to arid environments, shedding light on the role of gene duplication and regulatory modifications in metabolic evolution (Amin *et al*., 2019; Garcia, 2021).

Additionally, molecular clock analyses have helped estimate divergence times and historical biogeography, elucidating how geological and climatic events have influenced

the diversification of *Kalanchoe* species across different regions (Eggli and Nyffeler, 2010). These advancements in molecular research not only refine species classification but also enhance our understanding of ecological resilience, evolutionary trajectories, and potential applications in conservation genetics and horticultural breeding programs.

2.11 Phylogeny and Chromosome Number

According to Raadts (1989), the basic chromosome number for most of the East African *Kalanchoe* taxa is 2n = 34. However, variation exists, with some taxa exhibiting higher counts such as 2n = 68, approximately 2n = 102 and 2n = 126-135 (for example *K. boranae*), and 2n = 155-165 (*K. prittwitzii*). In an earlier study, Raadts (1984) recognized four distinct taxa—*K. boranae*, *K. prittwitzii*, *K. germanae* and *K. marmorata*—based on differences in chromosome numbers and vegetative morphology. She described *K. prittwitzii* as a heterogeneous complex comprising taxa with different ploidy levels. Consequently, she delineated two new species *K. germanae* and *K. boranae* using both morphological characters and cytological data. Notably, *K. germanae* (2n = 34) was regarded as a more primitive member of the genus, while *K. boranae* and *K. prittwitzii* represented more derived groups.

Uhl (1961) proposed that overlaps in chromosome numbers and morphological traits often indicate close evolutionary relationships. However, he cautioned that available data may sometimes be insufficient for conclusive taxonomic decisions. Raadts (1985) demonstrated that chromosome number could be used to distinguish between *K. lateritia* (diploid) and *K. crenata* (hexaploid) and their varieties. She also used both morphological intermediacy and

chromosome numbers to identify three hybrids viz., *K. nyikae* subsp. *auriculata* × *K. glaucescens, K. rotundifolia* × *K. glaucescens, K. lateritia* × *K. crenata*. One of these hybrids *K. nyikae* subsp. *auriculata* × *glaucescens* was revisited by Smith and Figueiredo (2019). In their revision while *K. nyikae* subsp. *auriculata* was recognized as *K.* × *auriculata* supported by its chromosome number (2n = 68) which differs from that of *K. nyikae* subsp. *nyikae* (2n = 34).

2.12 Ethnobotany of *Kalanchoe*

Ethnobotanical documentation of *Kalanchoe* species remains fragmented and uneven across regions despite their long history of cultural, medicinal and ornamental use. Globally, species within the genus are widely incorporated into traditional medicinal systems in Africa, Asia and South America−particularly in India, Brazil, Indonesia, Madagascar and East Africa—where they are used in both human and veterinary remedies (Sharmin *et al*., 2016; Kuo *et al*., 2018; Richwagen *et al*., 2019). In Uganda and Tanzania, for example, *K. glaucescens, K. rotundifolia* (Haw.) Haw. and *K. lanceolata* are commonly administered to treat infections, sore eyes, rheumatism and inflammatory conditions (Lye *et al*., 2008; Tolo *et al*., 2023).

In Kenya ethnomedicinal reports describe the use of *K. densiflora*, *K. germanae*, *K. lanceolata* and *K. pinnata* for managing dermatitis, wound infection and blood detoxifying (Kipkore *et al*., 2014; Kirui *et al*., 2014; Kigen *et al*., 2017). However, compared with other medicinal genera, detailed knowledge on traditional preparation methods, dosage, toxicity and cultural significance of *Kalanchoe* in Kenya is still limited. This reflects a

broader global pattern in which ethnobotanical information on *Kalanchoe* is abundant in anecdotal or scattered accounts but remains scientifically under-documented.

Beyond traditional medicine, several *Kalanchoe* species hold significant ornamental, horticulture and emerging industry value (Chang and Huang, 2018; Smith and Figueiredo, 2020; Kuang *et al*., 2021). Internationally, species such as *K. blossfeldiana* Poelln. and *K. thyrsiflora* Harv. are commercially cultivated for the floriculture market, with major breeding programs in Europe and Asia producing compact, drought-tolerant cultivars for the global houseplant industry (Chang and Huang, 2018; Smith and Figueiredo, 2020). In the biomedical and pharmaceutical sectors, *Kalanchoe*-derived bufadienolides and flavonoids have attracted interest due to their antiviral, immunomodulatory, antitumor, anti-ulcer and antimicrobial properties, leading to ongoing bioprospecting efforts and experimental drug-development studies (Kołodziejczyk-Czepas and Stochmal, 2017; Rahman *et al*., 2019; Stefanowicz-Hajduk *et al*., 2023). Yet, despite these advances, Kenya has not significantly leveraged *Kalanchoe* species for commercial horticulture, value-added medicinal products, or biomedical research, leaving a substantial gap between global potential and local utilisation. Overall, while *Kalanchoe* has clear ethnomedicinal importance and expanding global economic relevance, its ethnobotany—particularly in Kenya—remains underexplored. This necessitates comprehensive studies to document local knowledge, evaluate species-specific uses, and identify opportunities for sustainable utilization, conservation, and commercial development.

2.13 Bioactive Compounds of *Kalanchoe*

The genus *Kalanchoe* is recognized for both its ornamental value and traditional medicinal applications across cultures. Phytochemical studies have identified bioactive compounds such as flavonoids, phenols and bufadienolides in *Kalanchoe* species, exhibiting antiviral, sedative, anti-ulcer, antitumor, immunomodulatory, anti-inflammatory and antimicrobial properties in species such as *K. integra* (Medik.) Kuntze, *K. pinnata*, *K. delagoensis* and *K. crenata* (Kołodziejczyk-Czepas and Stochmal, 2017; Rahman *et al*., 2019; Stefanowicz-Hajduk *et al*., 2023). Phytochemical investigations have identified two primary classes of bioactive compounds in *Kalanchoe* species: bufadienolides and flavonoids (Milad *et al*., 2013).

Bufadienolides, a group of C-24 steroids with characteristic six-membered lactone ring at the C-17β position, have been predominantly reported in *K. daigremontiana*, *K. delagoensis* and *K. pinnata* (Kolodziejczyk-Czepas and Stochmal, 2017; Nascimento *et al*., 2023). These compounds exhibit notable cytotoxic and antitumour properties. For instance, bryophyllin A, found in *K. ceratophylla* Haw. *K. delagoensis* and *K. pinnata* has demonstrated antitumor activity across eleven cancer cell lines (Lozano-Milo *et al*., 2020; Assis de Andrade, 2023). Similarly, bersaldegenin-1,3,5-orthoacetate induces DNA damage, oxidasive stress and G2/M cell cycle arrest across nine cancer cell lines, including HeLa cells (Kolodziejczyk-Czepas and Stochmal, 2017; Stefanowicz-Hajduk *et al*., 2021, 2023).

Flavonoids also constitute a significant group of secondary metabolites, contributing to their antioxidant and anti-inflammatory properties of *Kalanchoe*. Phenolic profiling phenolic indicate that *K. daigremontiana* and *K. pinnata* contain particularly high amounts of ferulic and protocatechuic acids, corresponding with strong antioxidant activities with IC50 values ranging from 49.9 to 1410 μg/mL.(Bogucka-Kocka *et al*., 2018; Garcia-Perez *et al*., 2021). Cytotoxic assays further reveal that extract of *K. pinnata* show high activity against the H-9 human T cell line, while *K. daigremontiana*, *K. milloti* Raym.-Hamet and H. Perrier, and *K. nyikae* show pronounced cytotoxicity against J45.01 humans acute lymphoblastic leukemia T cells (Bogucka-Kocka *et al*., 2018; Singh *et al*., 2022).

Collectively, these findings suggest that *Kalanchoe* species are promising sources of natural antioxidants and potential anticancer compounds, supporting its traditional ethnobotanical applications and highlighting opportunities for future biomedical product development−an area particularly under explored in Kenya.

2.14 Threats to the Genus *Kalanchoe*

Many *Kalanchoe* species occur in vulnerable coastal habitats, while others naturally occur in degraded places that might be assumed to be less sensitive to disturbance and appear to be in decline. Habitat fragmentation and environmental degradation pose significant threats to *Kalanchoe* and other plants populations in East Africa (Stévart *et al*., 2019; Couvreur *et al*., 2021; Ogwu *et al*., 2022). Anthropogenic activities such as agriculture, deforestation, and infrastructure development exacerbate these threats (Mutwiwa *et al.*, 2018; Githitho, 2021; Musyoka, 2021). The unexpected economic and agricultural loss caused by drought

has made the Kenyan government emphasise issues of climate variability and encourage afforestation (Owino, 2022; Kirea and Wasiaya, 2023; Detelinova *et al*., 2023) as a move towards Vision 2030.

2.15 Conservation Assessments and Status of *Kalanchoe*

The genus *Kalanchoe* comprises 175 many species, 19 of which are native to Kenya (POWO, 2025). Conservation assessments of these species are essential for understanding their ecological status and ensuring their long-term survival. However, despite the recognized need for updated assessments, many *Kalanchoe* species remain understudied in terms of their conservation status. Walter and Gillett (1998) first highlighted the necessity of revising *Kalanchoe* species conservation records, a concern reiterated by the IUCN (2025), which emphasises the importance of reassessing species in light of habitat loss, climate change, and other ecological pressures. Currently, only 23 *Kalanchoe* species worldwide have been evaluated and included in the IUCN (2025) Red List by the World Conservation Monitoring Centre (See Appendix 1 for some of the *Kalanchoe* species in the Red List with the threat status indicated).

Within Kenya, 19 *Kalanchoe* species have been documented, yet only six have been formally assessed and listed. These include *K. ballyi* (Endangered, EN), *K. densiflora* (Least Concern, LC), *K. fadeniorum* (Extinct in the Wild, EW), *K. lateritia* (Least Concern, LC), *K. nyikae* (Least Concern, NT), and *K. obtusa* (Vulnerable, VU). The absence of comprehensive assessments for the remaining 13 species necessitates further research and conservation action. The varying conservation statuses of these species

highlight the different levels of risk they face. *Kalanchoe ballyi*, for instance, is classified as Endangered due to severe habitat destruction and over-collection. In contrast, *K. densiflora* remains in the Least Concern category, benefiting from a relatively stable population. *Kalanchoe fadeniorum* has already been declared Extinct in the Wild, with no known surviving wild populations since its last recorded observation in 1977. Meanwhile, *K. nyikae*, categorised as LC, is experiencing increasing habitat degradation, while *K. obtusa* is classified as Vulnerable due to ongoing fragmentation and habitat destruction.

A recent study by Smith *et al*. (2022) reviewed the conservation status of *Kalanchoe* species in southern Africa and emphasised that while some species remain widespread, those with restricted distributions are at significant risk. Additionally, Smith (2023) documented the spread of exotic *Kalanchoe* taxa across Africa, particularly species such as *K. pinnata*, *K. prolifera* (Bowie ex Hook.) Raym.-Hamet, and *K. delagoensis*, which have naturalized and become invasive in certain regions. In Kenya, coastal forest studies have recorded species such as *K. nyikae*, *K. lateritia*, and *K. obtusa*, providing critical data on their habitats and distribution (Ngumbau *et al*., 2020).

Despite the limited number of *Kalanchoe* species currently assessed in Kenya, the need for updated and comprehensive assessments remains urgent. The existing Red List classifications provide a foundation for conservation planning, but the exclusion of 13 species from formal assessment suggests that many may be at risk but lack sufficient data. Therefore, further studies, incorporating ecological surveys, population monitoring, and

conservation interventions, are necessary to ensure the protection and sustainability of Kenya's *Kalanchoe* species in their natural habitats.

CHAPTER THREE

MATERIALS AND METHODS

This chapter outlines the study area, field studies, data collection procedures for morphometric, phylogenetic, ethnobotanical and conservation studies and the analytical techniques used in this research.

3.1 Study Area

This study focused on the genus *Kalanchoe* in Kenya, within East Africa, designated as the *Flora of Tropical East Africa* (Figure 2.3). Six out of the seven Flora regions (K2–K7) (K2-Turkana, K3- Rift Valley, K-4 Central, K5- Nyanza, K6- Maasai, and K7- Coastal Provinces) have a high diversity of *Kalanchoe* species, known partially for their medicinal value. Northern Frontier (K1) was excluded from field surveys due to accessibility challenges but included in the systematic and conservation studies using herbarium specimens.

The genus *Kalanchoe* is highly diverse in the Rift Valley (Uasin Gishu, Nakuru, Naivasha, Nyahururu, Narok, Trans Nzoia, Kericho), Nairobi, Central (high plateaus- Kirinyaga), Central highlands (Kiambu, Thika, Nyandarua) Eastern (Embu, Machakos, Kitui) semi-arid and arid zones–North Eastern (Maasai), Coastal area (Taita, Kilifi, Mombasa, Kwale) and Western (Mt. Elgon) regions. This study was conducted across selected counties within the *FTEA* regions in Kenya representing the ecological and cultural range in which *Kalanchoe* species occur, are traditionally used, and face varying levels of conservation pressure (See Figure 3.1). The sites include highland agricultural counties (Uasin Gishu, Trans Nzoia, Kericho, Nyandarua, Kirinyaga, Kiambu), Rift Valley mosaics (Nakuru,

Naivasha, Narok), semi-arid and Eastern counties (Machakos, Kitui, Embu, Makueni), coastal regions (Taita-Taveta, Kilifi, Kwale, Mombasa), and urban-peri-urban landscapes around Nairobi, Naivasha, Nakuru and Eldoret.

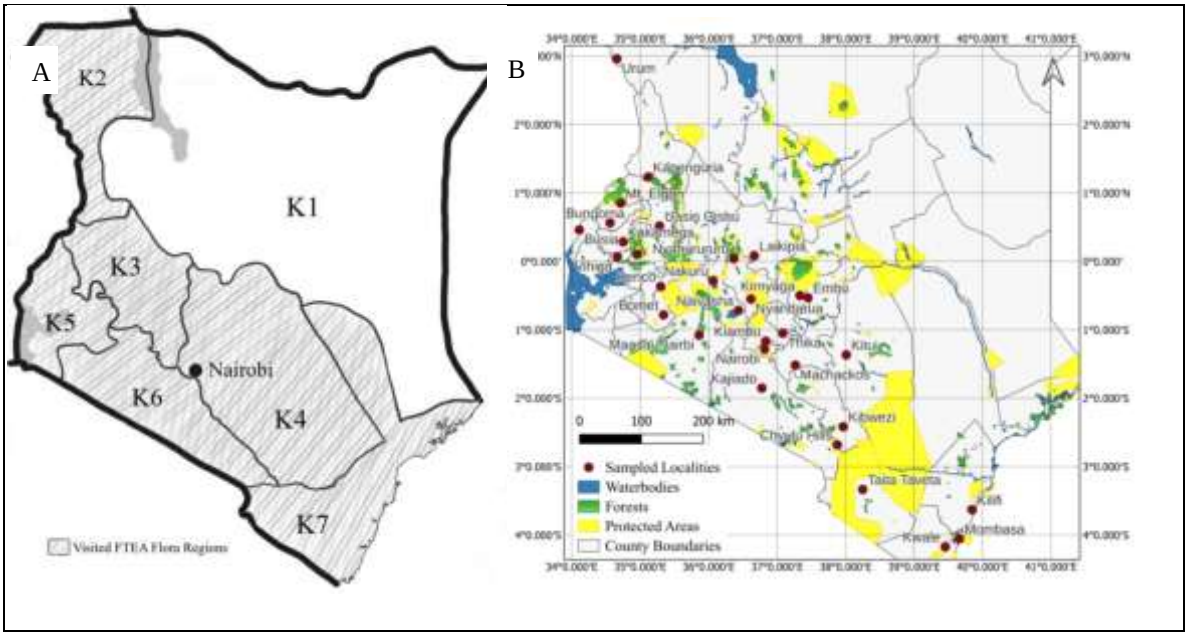

Figure 3.1. Map of Kenya Showing Floral Regions and Collecting Localities Visited During Fieldwork Mapped According to the: (A) *Flora of Tropical East Africa* (*FTEA*) Regions and (B) County Boundaries.

The 2019 Kenya Population and Housing Census shows considerable demographic variation within these regions—for instance, Nairobi hosts over 4.4 million residents while semi-arid Kitui and Taita-Taveta have populations below 1.2 million—reflecting differences in settlement intensity, resource use, and cultural diversity (Kenya National Bureau of Statistics (KNBS), 2019). These counties also encompass several ethnolinguistic communities, including the Kalenjin, Kikuyu, Luhya, Kisii, Maasai, Akamba, Embu, Mijikenda, and coastal Swahili groups, many of whom maintain long-

standing traditions of herbal medicine, ritual plant use, and household plant management practices relevant to *Kalanchoe* ethnobotany (Dharani, 2020) (See Table 3.1).

Ecologically, the study regions represent Kenya's main vegetation zones—ranging from moist highland forests and shrublands to dry woodlands, savannahs, and coastal thickets—each supporting distinct patterns of *Kalanchoe* distributions and species abundances (Beentje, 1994). Land-use patterns across the study sites—including intensive smallholder agriculture in the highlands, pastoralism in Narok and the rangelands, horticulture in Naivasha, and mixed farming and settlement expansion in Eastern and coastal counties—have significant implications for local plant populations, with habitat modification and overharvesting reported as emerging threats to medicinal succulents (Wekesa *et al*., 2020). This ecological and cultural diversity makes the selected study areas ideal for examining how traditional knowledge, livelihood systems, and land-use change interact to influence the ethnobotanical uses and conservation status of *Kalanchoe* species in Kenya.

Table 3.1 shows the distribution of *Kalanchoe* species in the study sites, communities representation and phenology.

Table 3.1 Study Sites, *Kalanchoe* Species Distribution and Phenology

Flora Region	Geographical Facts	Communities	Study Site(s)	Selected Species	Distribution	Phenology
K1 – North Eastern	Rocky areas; humid–dry mix	Somali, Boran, Rendile	Herbarium specimens	*K. densiflora*, *K. marmorata*	Herbarium locality records	Variable
K2 – West Pokot and Turkana	Semi-arid highlands	Pokot, Turkana	Shrublands and homesteads	*K. densiflora*, *K. pinnata*	Scattered wild and cultivated	Jun–Sep
K3 – Rift Valley highlands	Cool highlands, forest margins	Kalenjin	Agricultural lands, grasslands	*K. densiflora*, *K. glaucescens*, *K. marmorata*	Scattered natural populations	May–Aug
K4 – Eastern Kenya	Drylands, rocky soils	Kamba, Kikuyu, Maasai	Dry woodlands, rocky hills	*K. nyikae*, *K. marmorata*, *K. densiflora*	Common in semi-arid zones	Jan–Mar, Oct–Dec
K4 – Nairobi	Urban highland margins	Kamba, Kikuyu, Maasai	Forest edges, gardens	*K. densiflora*	Ornamental/escaped	Yr-round, peak Mar–Jun
K4 – Central (Kirinyaga)	Highland farms	Kamba, Kikuyu, Maasai	Highland farms	*K. densiflora*, *K. marmorata*	Semi-wild/cultivated	Apr–Jul
K4 – Central Highlands	Highland slopes	Kamba, Kikuyu, Maasai	Hill slopes	*K. densiflora*, *K. nyikae*	Patchy distribution	Jun–Sep
K5 – Western Kenya (Mt. Elgon)	Forested and agricultural	Luhya groups	Forest margins	*K. densiflora*	Localized	Jul–Oct
K6 – Narok/Maasai region	Grasslands, savannas	Maasai	Not sampled	–	–	–
K7 – Taita Taveta / Coast uplands	Rocky escarpments	Mijikenda, Taita, Swahili	Coral rag, gardens	*K. marmorata*, *K. pinnata*, *K. densiflora*	Frequent, naturalized	Feb–May

The ethnobotanical survey gathered data on local names, uses, harvesting methods, preparation (if medicinal), and cultural significance of *Kalanchoe* in communities near its natural localities. Field visits for ethnobotanical data collection, threat assessments and specimen gathering were conducted between August 2019 and December 2020. The study sites were selected based on species locality, distribution, and phenological information (Wickens, 1987) and *Kalanchoe* collections at the East Africa Herbarium (EA), Nairobi. Since most *Kalanchoe* species flower and/or fruit between March and June, fieldwork targeted specimens in flowering or fruiting stages (Wickens, 1987; Agnew, 2013) (See Appendix 12 for Photographs taken during field, herbarium and laboratory studies).

3.1.1 Study Design

The study entailed the use of a mixed-method design that integrated qualitative descriptive and quantitative including experimental approaches. Ethnobotanical and conservation data were gathered through surveys and field studies involving local communities and stakeholders, allowing for the documentation of ethnobotanical uses and threats to *Kalanchoe* species. Concurrently, morphological and molecular analyses were conducted using standard taxonomic and phylogenetic procedures. Field sampling followed a random sampling strategy, with collections made at approximately 50 km intervals along roads, forest margins, and bushlands in areas with high plant abundance or where target species were available. Additional data were obtained through herbarium studies, DNA extraction and sequencing, and subsequent bioinformatics analysis.

3.1.2 Sampling Scope

To obtain a comprehensive understanding of the phylogenetic relationships within the genus *Kalanchoe*, this study incorporated a broad taxonomic sampling, including taxa from Madagascar, other African countries, Arabia, and Asia. Madagascar, recognized as a potential center of diversity, was particularly emphasized due to its unique endemism and evolutionary significance (Gehrig *et al*., 2001; Rodewald *et al*., 2025). Recent efforts, including the use of ddRAD sequencing (Rodewald *et al*., 2025), have enhanced our understanding of phylogenetic relationships but highlight the need for additional sampling across the entire distribution range.

3.2. Field Surveys, Specimen Collection and Identification

Field expeditions were conducted between August 2019 and December 2020 to validate known localities and document new populations of *Kalanchoe* species. Surveys were conducted in areas with high species diversity across the six flora regions (K2 to K7). During fieldwork, plant specimens were collected, identified and later determined using *FTEA* keys (Wickens, 1987) and comparison with East African Herbarium (EA) specimens. Voucher specimens of *Kalanchoe* were collected, pressed, dried, mounted following standard botanical collection protocols (Smith and Chinnappa, 2015) and deposited at EA, Nairobi (See Appendix 4). Global Positioning System (GPS) coordinates, specimen and habitat descriptions, and population densities were recorded for each species.

3.2.1 Ethical Considerations

Informed consent was obtained from all participants, and confidentiality was ensured by anonymizing personal information. Participants were informed of their right to withdraw from the study at any time without consequences. Ethical approval was granted by the School of Graduate Studies, Kenyatta University, and the National Commission for Science, Technology and Innovation (NACOSTI) under permit reference (Ref. No. 937969) (See Appendix 13 and 14). Local administration and security authorities were consulted where necessary.

3.2.3 Study Limitations

This study was limited to communities and ethnic groups within the K2-K7 (K1 not visited) flora regions and specific *Kalanchoe* localities. Availability of K*alanchoe* specimens at the time of field visits also influenced data collection outcomes. Sample size was influenced by the availability of informants in *Kalanchoe* localities visited and their willingness to share information. The Covid-19 pandemic further restricted movement and interactions in some parts of the country.

3.3 Morphological Studies

Morphological character evaluation included observation and coding of qualitative characters (18) as well as measurement of vegetative and floral quantitative characters (37) totalling to 55 characters. The schematic summary of the herbarium study and data analysis is shown in Figure 3.2.

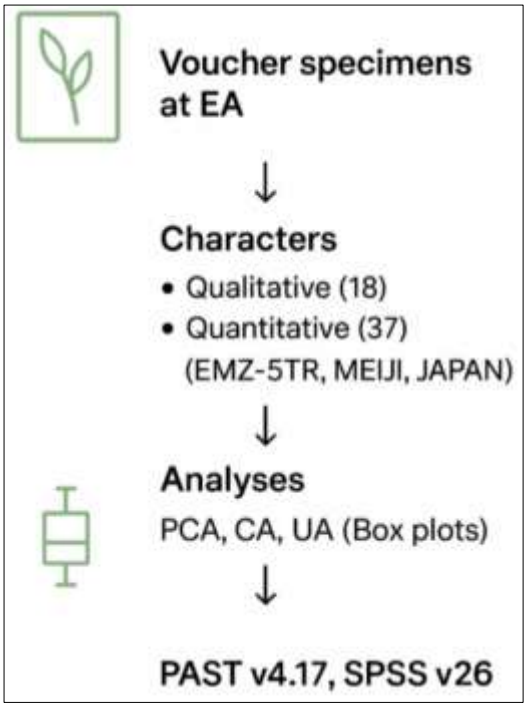

Figure 3.2 A Schematic Summary of the Morphometric Study Methods.

3.3.1 Morphological Character Measurements

Specimens were selected based on possession of flowers and/or fruits in addition to vegetative characters (Martínez-García *et al*., 2022) (See Appendix 5). Measurements using a ruler and dissecting microscope (EMZ-5TR, MEIJI, JAPAN) included; Quantitative characters: flower number and length, calyx length, corolla diameter, corolla tube and limb length, petals number, pedicel length, filament length, anther length, stamen number, style length and seed length and thickness. Qualitative characters; flower type, sepal's fusion and papilla, petals fusion and colour, corolla shape, stamen attachment, carpels fusion, style shape and leaf arrangement, apex, connation and sheath (Tables 3.2

and 3.3). Rehydration was done for herbarium specimens before measurements using warm water. Morphological character data matrix was made for morphometric analyses (See Appendix 7).

Table 3.2. List of Quantitative Characters.

Character	Character State
Leaf	1. Leaf blade length (LBL)
	2. Leaf width (LW)
	3. Petiole length (PL)
Flower	1. Inflorescence length
	2. Flower length (FL)
	3. Pedicel length
Calyx	1. Calyx lobes length (CLL)
	2. Calyx lobes width (CLW)
	3. Calyx connation at the base (CCB)
Corolla	1. Diameter of corolla (CD)
	2. Length of corolla tube and limb (CL)
	3. Petals number (PN)
Androecium	1. Filament length (FL)
	2. Anther length (ANL)
Gynoecium	1. Length of style (STYL)
	2. Carpels length
	3. Seed length
	4. Seed thickness

Table 3.3. List of Qualitative Characters

Character	Character State
Flower type (FT)	Solitary (0), Inflorescence (1)
Flower length in relation to leaves(FLL)	Shorter than subtending leaves (0), Longer than subtending Leaves (1)
Sepals fusion (SF)	Free (0) United (1)
Sepals papilla (SPA)	Without papilla(0), With papilla (1)
Petals fusion (PF)	Free (0) Fused (1)
Petals colour (PC)	White (0), Cream (1), Red (2), Pink (3)
Corolla shape (CS)	Not five-angled (0), Five-angled (1)
Leaf arrangement (LAR)	Opposite (0), Alternate (1), Whorled (2)
Leaf apex (LA)	Not thickened (0), Slightly thickened (1), Thickened (2)
Leaf connation (LCO)	Not connate (0), connate (1)
Stamens attachment (SA)	Episepalous (0), Gamopetalous (1)
Carpels fusion (CF)	Free (0), united (1)
Style shape (SS)	Subulate (0), cylindrical (1)
Leaf sheath (LSH)	Less than 1cm long (0), More than 1 cm long (1)
Leaf pubescence	Pubescent (0), Not pubescent (1)
Stem pubescence	Pubescent (0), Not pubescent (1)

3.3.2 Morphological Data Analyses

Morphological data were analysed using the PAST version 4.17 program. A data matrix, comprising 37 quantitative character measurements and 18 qualitative character scores (See Appendix 6) was subjected to multivariate analyses using different distance methods. Ordination techniques were applied to confirm presumed relationships among the Operational Taxonomic Units (OTUs) and to identify the most effective characters for

species delineation. Additionally, Univariate Analysis (UA) using box plots was used to illustrate character variation among different groups. Principal Component Analysis (PCA) projected data onto axes of maximal variance, while Cluster Analysis (CA) was performed to investigate potential phylogenetic relationships amongst OTUs. The analyses utilised the Unweighted Pair-Group Method using Arithmetic Averages (UPGMA) and distances calculated using Euclidean Distance Coefficient and Jukes-Cantor distance (Singh *et al*., 2014; Yin *et al*., 2014).

3.4 Molecular Studies

Molecular studies entailed sample collection and preservation, DNA extraction, library preparation and sequencing for 80 samples representing *Kalanchoe* genus in Africa and Asia. A summary of the molecular study methods from sample collection to generation of phylogenetic trees is illustrated in Figure 3.3.

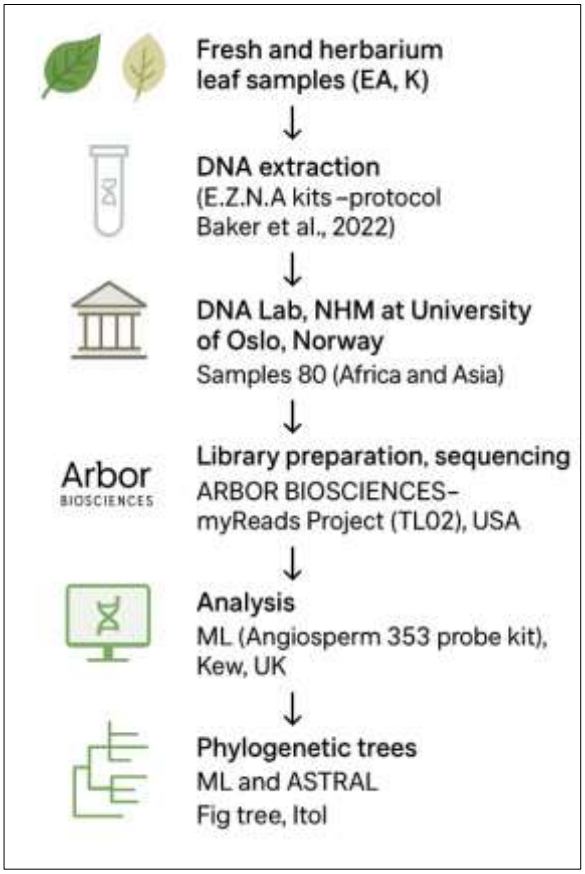

Figure 3.3. A schematic illustration of the Molecular Study

3.4.1 Sample Collection and Preservation

Fresh young leaf samples from *Kalanchoe* species were cleaned using wet soft tissue and wiped dry then stored in silica gel (Chase and Hills *et al*., 1991) in sealed containers at room temperature. The silica gel was checked regularly for colour change and replacement. Upon confirmation of no further colour change the samples were kept and later transferred to the Natural History Museum (NHM) at the University of Oslo for molecular studies in the DNA laboratory.

3.4.2 Extraction, Library Preparation and Sequencing

Samples stored in silica gel and those from East African Herbarium and Royal Botanical Gardens, Kew (K) were transferred to the Natural History Museum at University of Oslo, where they were stored and used for molecular work (See Appendix 8). Deoxyribonucleic acid (DNA) was extracted from leaf tissue following the protocol outlined by Baker *et al*. (2021, 2022). About 20 mg frozen (at -20°C for about 1hr) dry leaf tissue sample was ground to a fine powder in a 2ml tube containing two tungsten-carbide beads using a TissueLyser adapter (Retsch MM 400) for 1 minute for two rounds at 25 Hz speed. Deoxyribonucleic acid was isolated from the leaf tissue using the E.Z.N.A tissue DNA Kit following the manufacturer's instructions, with slight modifications (Doyle and Doyle, 1987; Doyle, 1991) (See Appendix 10 for DNA extraction Protocols).

The quality and quantity of the extracted DNA was assessed through dsDNA quantification analysis **(**Nanodrop One, ThermoScientific), fluorometry (Qubit® 2.0, Life technologies), and gel electrophoresis to determine fragment sizes by running the samples for 45 minutes on 1% agarose gel at 9V (See Appendix 10 for protocols used in the gel electophoresis and Appendix 11 for the micrographs). This ensured efficiency during library preparation and sequencing (Andermann *et al*., 2020). The DNA samples were then sent to ARBOR BIOSCIENCES- myReads Project (TL02-Demultiplexing stats-2jk) for sequencing.

Prior to library preparation, DNA fragments with average size above 350 bp were sonicated to this size in microTUBEs AFA Fiber Pre-Slit Snap-Cap using a ME2020

Focused-ultrasonicator (Covaris, Woburn, MA, USA) with the following parameters: peak power at 50 W, duty factor at 20%, and 200 cycles per burst; between 30 and 90s depending on each sample's fragment profile. Libraries were prepared using the DNA NEBNext Ultra II Library Prep Kit and NEBNext Multiplex Oligos for Illumina, utilising Multiplexing Dual Index Primers Set 1 and 2 (New England BioLabs, Ipswich, MA, USA) following the manufacturer's instructions with adjustment to half volume reactions (See Appendix 9). During library preparation, sonicated samples underwent double-end size selection using AMPure XP magnetic beads but for highly degraded samples, long fragments (single-end selection) were discarded.

Libraries were amplified by using polymerase chain reaction (PCR), with 7-12 cycles (New England Biolabs) and then cleaned to remove the adapter–primer–dimer using AMPure XP magnet beads. Library quality was assessed using D1000 ScreenTape on a 4200 TapeStation System (Agilent Technologies, Santa Clara, CA, USA) and quantified using the fluorometer. If the normalised library concentration was lower than 10nM, a second round of polymerase chain reaction was implemented, running 3-6 additional cycles followed by another round of cleaning and quality assessment. The concentrations of genomic libraries were normalized to 10nM before pooling, and all normalisations were done using 10 mM Tris.

Genomic libraries were pooled according to their average fragment sizes, with each pool including 10–20 samples, ensuring that short-insert libraries (<300 bp) mixed with long-insert ones (>500 bp). For each pool, equal volumes of each normalized library were

added, aiming for a final amount of ~500 ng of DNA (roughly 10–20 μL per library). Pools were enriched using the myBaits Expert Angiosperms 353 v1 predesigned panel (Daicel Arbor Biosciences, Ann Arbor, MI, USA; Johnson *et al*., 2019) with chemistry v4 following the manufacturer's protocol. Hybridizations were performed at 60°C for small libraries or 65°C for 24 hours for average to large libraries.

The enriched pools were amplified for 12–14 PCR cycles using the primers IS5 reamp.P5 and IS6_reamp.P7 (Meyer and Kircher, 2010) and NEBNext Ultra II Q5 Master Mix (New England BioLabs) then cleaned using Agencourt AMPure XP magnetic beads at 0.9×. Final hybridized pools were quantified using the fluorometer and also run on the TapeStation System using D1000 ScreenTapes to assess quality and average fragment sizes. Hybridised pools were normalized to 6nM then combined into sequencing batches in equimolar amounts with around 200 enriched libraries per sequencing batch, and sequenced on a HiSeq platform (Illumina, San Diego, CA, USA).

3.4.3 Molecular Data Analysis

DNA sequence data were analysed under the maximum likelihood criterion (Andermann *et al*., 2020). Phylogenetic trees were constructed using: Maximum Likelihood (ML) analysis to examine evolutionary relationships and ASTRAL analysis to resolve species-level taxonomic complexities (Blischak *et al*., 2023). These methods provided insights into evolutionary and taxonomic relationships within the *K. lateritia* and *K. nyikae* complexes.

3.4.3.1 Sequence Recovery

The genetic relationships among *Kalanchoe* species were inferred using DNA sequence data analysed under the Maximum Likelihood criterion and ASTRAL with ModelFinder and tree visualised in FigTree. The ML approach was selected because it provides a statistical rigorous framework for phylogenetic influence by identifying the tree topology that maximises the likelihood of observing the given sequence data under an explicit model of molecular evolution. It accounts for heterogeneity in evolutionary rates among sites and lineages, thereby producing more accurate and reliable phylogenies. ASTRAL was employed to estimate the species tree from multiple gene trees under the multi-species coalescent model, effectively accommodating gene tree discordance arising from processes such as incomplete lineage sorting. This combination of ML and ASTRAL thus enhances the robustness and resolution of phylogenetic relationships among *Kalanchoe* species.

The bioinformatic workflow included data storage and backup, analytical pipelines, sequence cleaning, trimming, quality assessment, sequence assembly and extraction of sequences from assembled results (Andermann *et al*., 2020). Deoxyribonucleic acid (DNA) sequencing was conducted using the Angiosperm 353 universal probe set (Brewer *et al*., 2019; Andermann *et al*., 2020).

Raw sequencing files were processed using Trimmomatic 0.39 (Bolger *et al*., 2014) to remove adapter sequences and low-quality bases. Parameters included a leading and trailing end trim threshold of 30, sliding window trimming with a threshold of 30 (averaged over 4 bp), and a minimum read length of 36 bp. Sequence recovery was

performed using HybPiper 1.3.1 (Johnson *et al*., 2016) in two rounds. The first round focused on nuclear genes enriched with the Angiosperms 353 probe set, using a translated target file from the hybridization kit (Angiosperms 353.FAA). Trimmed reads were initially binned to genes using BLASTx (Camacho *et al*., 2009) and subsequently assembled *de novo* using SPAdes 3.13.1 (Bankevich *et al*., 2012). Coding nucleotide sequences were extracted, and flanking non-coding regions were removed using Exonerate 2.2 (Zhang *et al*., 2018, 2020). Recovery statistics were computed using HybPiper scripts such as get_seq_length.py, gene_recovery_heatmap.R, and hybpiper_stats.py. Transcriptomic data were obtained from the NCBI Sequence Read Archive (SRA) using the fasteq-dump tool (available at https://github.com/ncbi/sra- tools), and resulting raw data were treated as described above.

3.4.3.2 Phylogenetic Reconstructions Using Angiosperms 353 Nuclear Data Set

Nucleotide coding sequences from the 353 nuclear loci recovered from hybridised genomic libraries and transcriptomes (from NCBI SRAs) were combined, retaining only genes present in at least 10 taxa for down-stream analysis. The analysis pipeline consisted of two iterations of alignment, trimming, and gene-tree inference under maximum likelihood (ML), incorporating an outlier- taxon removal step to exclude sequences inflating gene tree diameter.

In both iterations, gene sequences aligned using MAFFT 7.310 (Katoh and Standley, 2013) with the L- INS- i method and with maximum iterations setting of 1000. Sites with <30% occupancy were removed using Phyutility 2.2.6 (Smith and Dunn, 2008). Maximum

likelihood gene trees were inferred using IQ- TREE 2.1.0 (Minh *et al*., 2020), with model selection implemented *via* ModelFinder (Kalyaanamoorthy *et al*., 2017) and branch support calculated using 1000 UltraFast Bootstrap replicates (Hoang *et al*., 2018). Following the first iteration, TreeShrink 1.3.4 (Mirarab and Mai, 2018) was applied to detect and eliminate excessively long branches (threshold at 0.05). Filtered gene sets were re-aligned and trimmed under the same parameters before ML gene tree estimation. Gene tree bipartitions with boot-strap support below 10% (Mirarab, 2019) were collapsed using Newick Utilities 1.6 (Junier and Zdobnov, 2010).

A multispecies coalescent tree (nc-MSC) was in ASTRAL-III 5.7.3 (Zhang *et al*., 2018) with full branch annotation of branches (-t 2 flag). Clade support was assessed by estimating local posterior probability (LPP). The trimmed gene alignments were concatenated and analysed as a partitioned data matrix (nc- CON tree) in IQ- TREE 2, followed by partition merging with ModelFinder. Clade support was determined using 1000 UltraFast Bootstrap replicates.

3.5 Ethnobotanical Study

This section covers sampling, data collection on uses of *Kalanchoe* and analysis methods as illustrated in Figure 3.4.

Figure 3.4. A schematic illustration of the Ethnobotanical Study

3.5.1 Sampling Methods

The study employed purposive sampling to identify initial informants in or near known localities of *Kalanchoe* species who had knowledge of their presence, names, uses, and population changes. The ethnobotanical survey targeted adult informants (aged 18 and above). A snowball sampling technique was used to recruit additional informants (Parker *et al*., 2019). The final sample consisted of 83 informants, stratified by age groups (18-20, 21-40, 41-60, 60 and above), gender, occupation (teacher/lecturer, medical professional, (medic—doctor/nurse), engineer, farmer/pastoralist, businessman, herbalist, and others), education level (primary, secondary, tertiary, informal, and none) and ethnicity. The study

targeted 120 informants, but only 83 were willing to share information (See Questionnaire in Appendix 2).

3.5.2 Data Collection

Data was collected through semi-structured interviews using open-ended questions designed to explore the medicinal and other uses of *Kalanchoe* (Naderifar *et al*., 2017). The questionnaire covered: Botanical and local names, uses (medicinal and non-medicinal), plant parts used, preparation and administration methods (if medicinal), cultivation status (wild, potted or garden-grown), weedy nature and harvesting techniques, conservation efforts and threats (See Questionnaire in Appendix 2).

The specific uses were categorized, and disease classifications for *Kalanchoe* species were standardized using Cook (1995) and Staub *et al*. (2015). The prevalence of different *Kalanchoe* uses was recorded and quantified according to Weckerle *et al*., (2018a). Plant names and ethnobotanical information were cross-referenced with records from Wickens (1987), Agnew (2013), and herbarium specimens.

3.5.3 Data Analysis

Demographic and species use data from the interviews were analysed. Key metrics included: Use Value (UV), Relative Frequency (RF), Informant Consensus Factor (ICF). Qualitative data were coded and analysed alongside quantitative data using Microsoft Excel 2016 and Paleontological Statistics Software Package for Education and Data Analysis (PAST).

The study investigated the following quantitative ethnobotanical indices:

(a) Use Value (UV)

A measure of the relative importance of a species.

Where: U is the number of use reports for a species and n is the total number of informants: $UV = U / n$ (Philip *et al*., 1994).

High UV indicates many use reports for the species in focus (high >0.300, moderate 0.200-0.300 and low <0.200).

(b)The Relative Frequency of citation (RFC)

Relative frequency of citation measures how frequently a species is mentioned: $RFC = FC / N$

Where: (FC) is the frequency of citation and N is the total number of informants (Vitalini *et al*., 2013).

("O"- nobody referred to the plant as useful and "1" - all informants referred to the plant as useful).

(c) Informant Consensus Factor (ICF)

Informant consensus factor evaluates consensus on plant use within disease categories: consistency of the data concerning certain sorts of disease categories: $ICF = (Nur - Nt) / Nur - 1)$.

Where: Nur is the total use report for a category and Nt is the number of taxa used (Heinrich *et al*., 1998; Canales *et al*., 2005; Sharma *et al*., 2012). High value (close to 1) predicts that the plants are used by the high percentage of the informants for a number of

illnesses related to that comprehensive category. Low value (close to 0) predicts that plants are selected arbitrarily for a few or a single complaint or that informants did not share or exchange facts and data about the usage of plants. Medicinal plants used to treat very few diseases are supposed to be pharmacologically less active and thereby have lower ICF (values).

Demographic and species use data from the interviews was analysed. Use value (UV), relative frequency (RF) used to identify the most common application of the plants, and informant consensus factor (ICF) to identify the most commonly used species were computed to assess the use value of different species of *Kalanchoe*. Qualitative data were coded and analysed together with quantitative data using Python Scripts, Microsoft Excel 2016 and Paleontological Statistics Software Package for Education and Data Analysis (PAST) version 4.17.

3.6 Conservation Study

This section covers conservation status assessment, data analysis.

3.6.1 Conservation Status Assessment Studies

Preliminary conservation assessments for the 19 *Kalanchoe* species were performed using the GeoCAT tool (http://geocat.kew.org/) to calculate the Area of Occupancy (AOO) and Extent of Occurrence (EOO). Occurrence data from field collections made using a handheld GPS across multiple Kenyan counties and herbarium and online records retrieved from the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/) and

institutional collections including the EA and Kew (Appendix 6). All georeferenced occurrence records were cleaned and standardised before being imported into GeoCAT as a CSV data file containing species name, latitude and longitude. The AOO was culculated automatically in GeoCAT using the standard IUCN 2 × 2 km grid cell size, which counts the number of occupied grid cells to estimate the species area of occupancy.

Field observations and local informant data on habitat conditions, anthropogenic threats, species utilisation and conservation efforts for a decade (2010-2020) were used to compliment the spartial analyses and support the preliminary IUCN Red List categorisation.

A full reassessment of the conservation status of *K. lateritia* and *K. nyikae*, along with their infraspecific taxa, was carried out based on the International Union for Conservation of Nature (IUCN) Red List criteria (IUCN, 2022). Factors considered included: population size and trends, habitat quality and degradation, threat severity and conservation measures.

The assessments followed the IUCN Red List criteria: Criterion A: Population decline assessments; Criterion B: Geographic range restriction; Criterion C: Small population size trends; Criterion D: Extremely small population risk; Criterion E: Quantitative extinction probability modelling. Species were categorised as Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Least Concern (LC), guiding conservation priorities.

3.6.2 Data Analysis

Spatial analysis of species distribution was performed using Geographic Information Systems (GIS) tools to map species occurrence and assess habitat fragmentation. Descriptive statistics were applied to summarize conservation threats.

3.6.2.1 Conservation Status Data Analyses

Preliminary conservation status of the 19 species was deduced by calculating the AOO and EOO of the taxa using the GeoCAT tool (http://geocat.kew.org/). Quantitative data was analysed using descriptive statistics in Microsoft Excel, 2016, the Paleontological Statistics Software Package for Education and Data Analysis (PAST version 4.17, Hammer, 2001) and Python scripts while qualitative data was coded and analysed alongside quantitative data using the same tools.

3.7 Data Analyses

Morphological, molecular, Ethnobotanical and conservation data was analysed using various statistical approaches to test the study objectives as outlined in each section.

CHAPTER FOUR

RESULTS

This chapter presents the research findings on the genus *Kalanchoe* in Kenya focusing on its taxonomic boundaries within the *K. lateritia* and *K. nyikae* species complexes, molecular and phylogeny, ethnobotany, threats and conservation status.

4.0 Demographic Patterns

Informants from neighbourhoods of *Kalanchoe* localities were targeted for the study, with 83 who had relevant knowledge agreeing to participate. Among them, 28 (32.5%) were female and 55 (67.5%) male, representing nine ethnic groups: Kalenjin, Kamba, Kikuyu, Kisii, Luhya, Luo, Maasai, Mijikenda and Taita. Age distribution and gender representation among informants are illustrated in Figure 4.1.

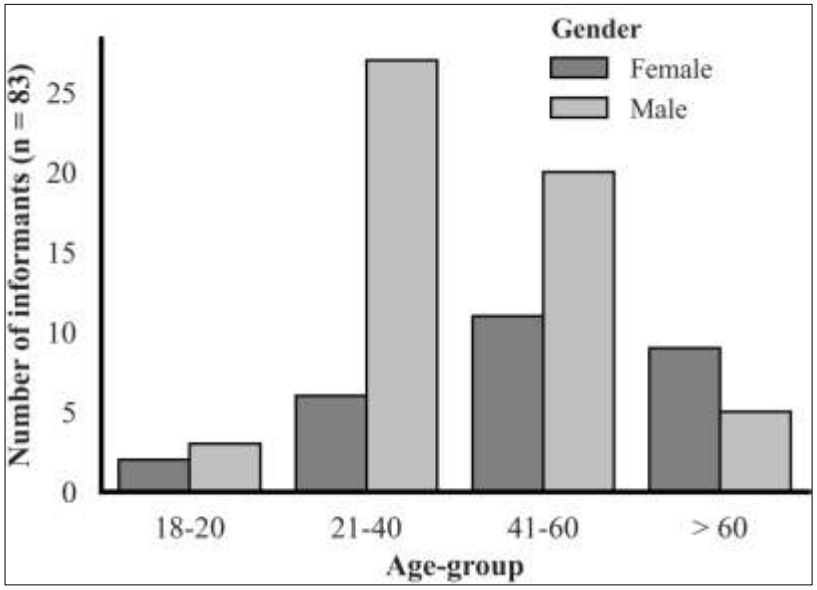

Figure 4.1. Respondents by Age and Gender in the *Kalanchoe* Study in Kenya.

From Figure 4.1, the 21–40 age group was the most represented, with a higher number of male informants. The 41–60 age group showed a fairly more balanced gender distribution, with men exhibiting more knowledge of medicinal uses of *Kalanchoe* and women demonstrating greater familiarity in the above 60 years' age group. Younger individuals (18-20) and older informants (above 60 years) had the least representation for both genders. Informants, especially male, aged between 21 and 60 were found carrying out activities in or near the habitats of *Kalanchoe* i.e., roadsides, rocky hillsides and shrublands. Majority of the herbalists who participated in the study were in this age bracket.

Occupational backgrounds of informants are illustrated in Figure 4.2.

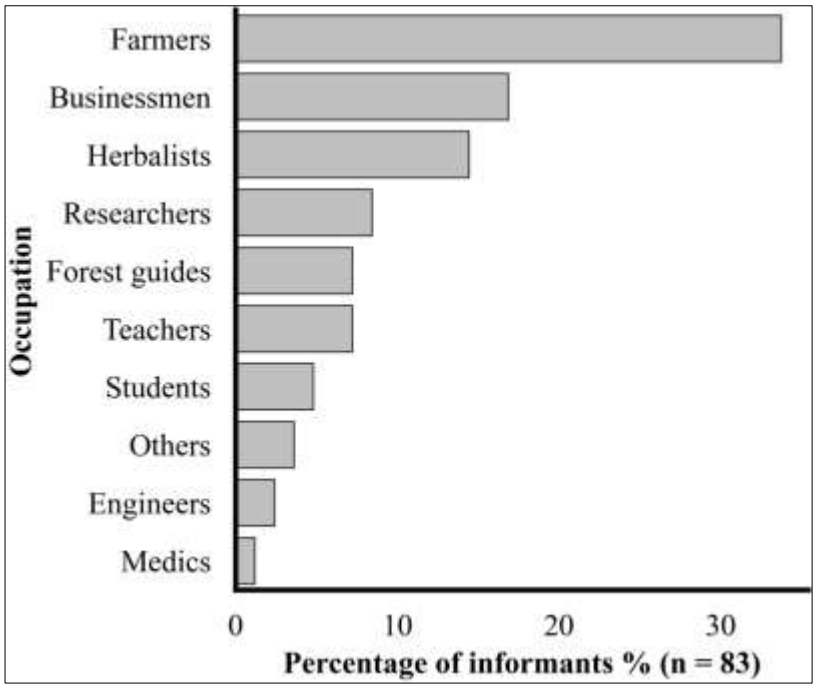

Figure 4.2. The Occupational Groups Interviewed During the *Kalanchoe* Study.

Among the categories listed in Figure 4.2, farmers exhibited the highest count, numbering about 30. Other categories such as teachers (including lecturers), researchers, forest guides/rangers, students, and those classified as "others" (quarry workers, casual workers and motorbike riders) demonstrated lower representation, with values falling below 10, while, occupations such as businessmen, and herbalists showed moderate representation, with values between 10 and 15. Education levels among the informants were fairly balanced, with representation across all categories—from no formal education to tertiary level—as shown in Figure 4.3.

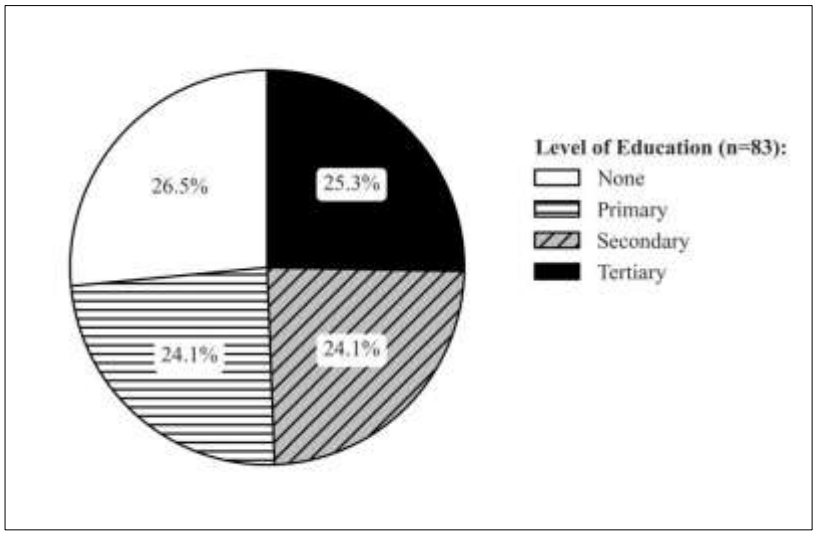

Figure 4.3. Education Level of the Respondents in the *Kalanchoe* Study Survey.

Ethnicity representation of the 83 informants and knowledge distribution across different *Kalanchoe* species are presented in Figure 4.4 A and B.

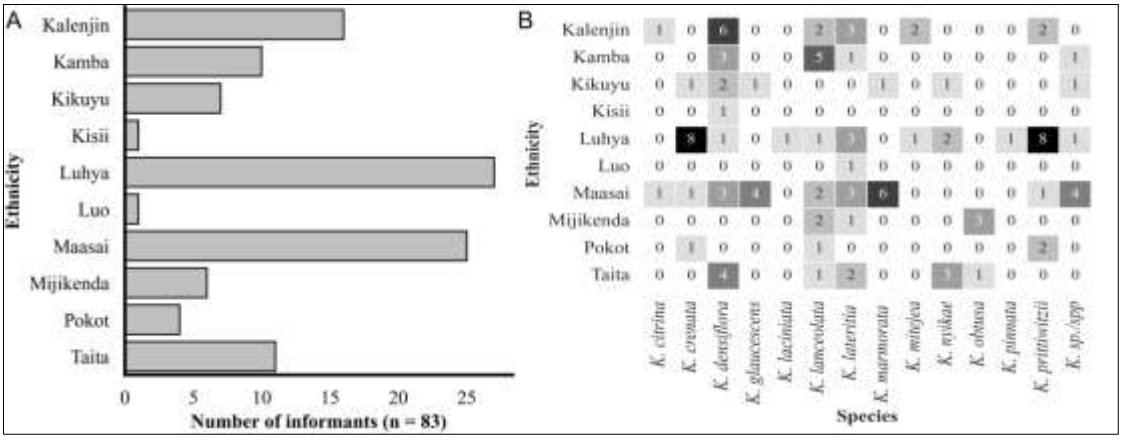

Figure 4.4. Ethnicity Represention During the *Kalanchoe* Study. A. in the Ethnobotanical Survey B. per species.

The data shows variation in sample sizes among ethnic groups, which was mainly affected by the distribution and availability of the plants within the user communities at the time of field visits. The intensity of shading represents the frequency of informants familiar with each species, ranging from low (light) to high (dark). The Luhya and Maasai had the highest number of informants, while the Luo and Kisii had minimal representation while the rest demonstrated moderate participation levels. On the other hand, Figure 4.4 B highlights substantial variation in familiarity with *Kalanchoe* species among ethnic groups. The Luhya group showed the highest citations of use, particularly for *K. crenata* and *K. prittwitzii*. Similarly, the Maasai exhibited notable familiarity with *K. marmorata*, the Kambas, *K. lanceolata*, and the Kalenjins, *K. densiflora*.

4.1 Taxonomic Circumscription in the *K. lateritia* and *K. nyikae* Complexes

This section gives the results of the morphometric investigation of the species and infraspecific boundaries in the *K. lateritia* and *K. nyikae* complexes. Morphological data

was obtained from 55 specimens representing the *K. lateritia* (42) and *K. nyikae* (21) species complexes. Fifty-five character states (37 quantitative and 18 qualitative) from vegetative, floral and seed characters were used in the study. Data from the type specimens of the two species was included in the analyses. The objective which guided the study was to investigate species boundaries within the *K. lateritia* and *K. nyikae* species complexes based on molecular and morphometric approaches.

4.1.1 Morphometric Analyses of *K. lateritia* Complex

Morphometric analyses: Principal Component Analysis (PCA), Cluster Analysis (CA) and Univariate Analysis (UA) revealed diverse patterns in the *K. lateritia* species complex.

4.1.1.1 Principal Component Analysis of the *K. lateritia* Complex

A Principal Component Analysis (PCA) was conducted with 42 OTU's representing the three recognised varieties of *K. lateritia* viz., *K. lateritia* var. *lateritia* (●), *K. lateritia* var. *prostrata* (△) and *K. lateritia* var. *pseudolateritia* (◇) using vegetative, floral and seed characters to explore patterns of variation among the three varieties. The Kaiser-Meyer-Olkin (KMO) test results value was approximately 0.68 suggesting the data is moderately suitable for factor analysis (between 0.5 and 0.7) and individual variable KMO values range from 0.52 to 0.81. The biplots (Figure 4.5 and 4.6) illustrate the distribution of individual OTU's along the first three principal components (PC1 against PC2 and PC3). The first three components accounted for a cumulative 98.96% of the total morphological variation, with Component 1 explaining 88.75%, Component 2 accounting for 9.52% and Component 3 for a further 0.69% (Table 4.1).

Table 4.1. Eigenvalues and % Variance of the *K. lateritia* Species.

PC	Eigenvalue	% variance
1	17016.000	88.75
2	1824.520	9.52
3	131.874	0.69

There were no distinct clusters of OTU's along the first, second and third components in the multivariate space as seen in the PCA analysis results (Figure 4.5 and 4.6). However, along the first component, *K. lateritia* var. *prostrata* almost forms a cluster towards the left and *K. lateritia* var. *pseudolateritia* towards the right with *K. lateritia* var. *lateritia* occupying the intervening space between the two varieties but intermingling more with *K. lateritia* var. *prostrata*. A similar pattern was also observed along the first and third components with *K. lateritia* var. *pseudolateritia* almost separating from the other two intermingled varieties but with a few of its OTU's remaining interspersed.

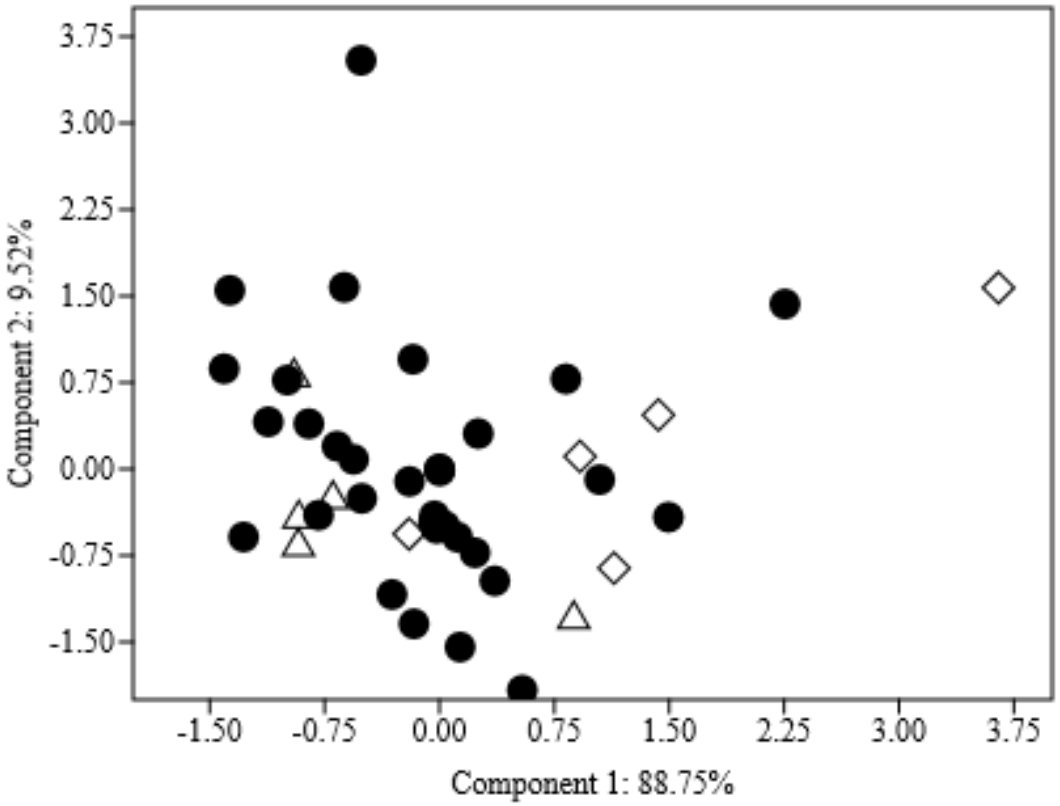

Figure 4.5. Scatter Plots of the 42 OTU's Plotted Against the First Component-Plane by the Second for *K. lateritia* Complex. *Kalanchoe lateritia* var. *lateritia* (●), *K. lateritia* var. *prostrata* (△) and *K. lateritia* var. *pseudolateritia* (◇).

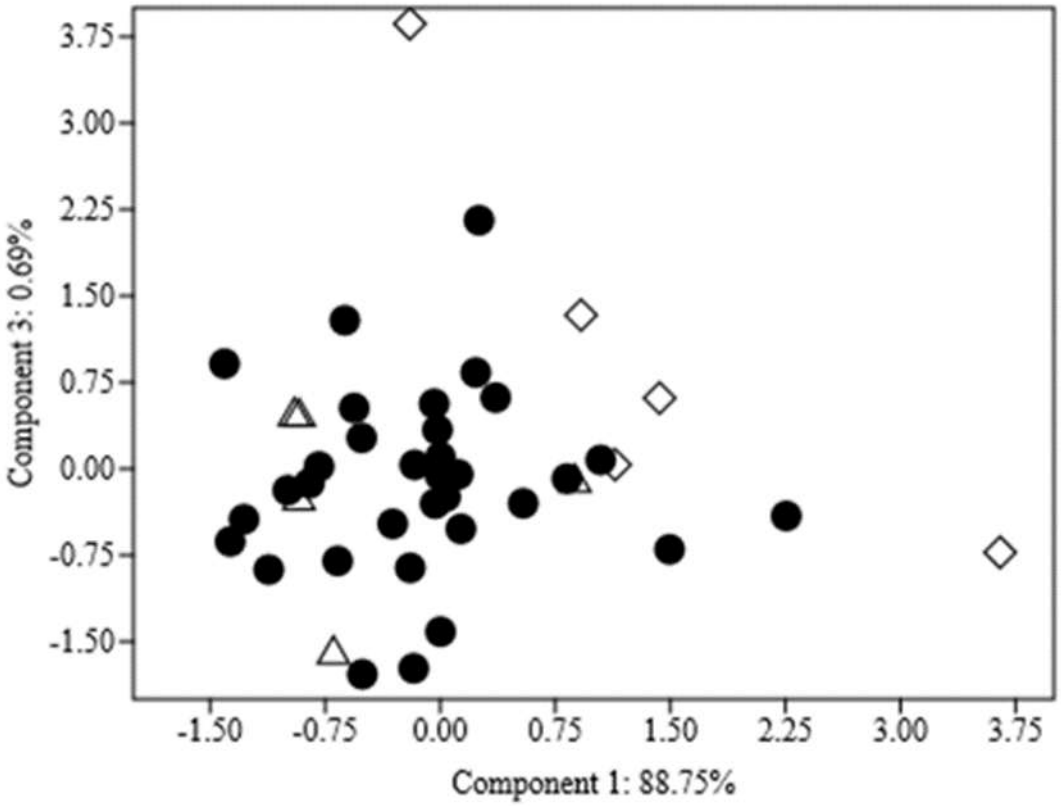

Figure 4.6. Scatter Plots of the 42 OTU's Plotted Against the First Component-plane by the Third for *K. lateritia* Complex. *Kalanchoe lateritia* var. *lateritia* (●), *K. lateritia* var. *prostrata* (△) and *K. lateritia* var. *pseudolateritia* (◇).

Kalanchoe lateritia var. *lateritia* exhibited the widest dispersion along both Component 1 and Component 2. Operational Taxonomic Units from this group were distributed across both negative and positive sides of Component 1 and were densely clustered near the origin, with minimal dispersion along the components.

In contrast, *K. lateritia* var. *pseudolateritia* formed a more distinct and compact cluster towards the positive axis of Component 1 and showed a broader spread across both axes, including outliers particularly in the upper and right-hand quadrants. *Kalanchoe lateritia*

var. *prostrata* was generally located in the negative region of Component 1, had limited spread and was largely embedded within the *K. lateritia* var. *lateritia* cluster. Some degree of overlap among the three varieties existed, especially between *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata*, Component 1 largely distinguished the varieties. Variance along PC1 was dominantly explained by Inflorescence Length (IL) with a very high loading of 0.97**,** the primary morphological feature distinguishing the varieties along this axis followed by Leaf Length (LL) (0.19) and Leaf Base Length (LBL) (0.15) and PC2 (9.52% variance influenced by Leaf Length (LL) = 0.74, Leaf Base Length (LBL) = 0.53, and Leaf Width (LW) = 0.30**.** Principal component **(**PC3) explained almost negligible variance highlighting variation in leaf width (LW) and other minor vegetative traits.

4.1.1.2 Cluster Analysis of the *K. lateritia* Complex

Cluster Analysis of 42 OTU's of *K. lateritia* done using Euclidean and repeated using Jukes-cantor (p>0.75) distances for clarity (See Figure 4.7). No distinct clusters of the three varieties of *K. lateritia* were observed. *Kalanchoe lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* were intermingled with *K. lateritia* var. *lateritia* in small clusters within the main clade. In Figure 4.7 two main sub-clusters can be recognized. The first sub cluster consists of *K. lateritia* var. *lateritia* individuals intermixed with those of *K. lateritia* var. *prostrata* except for the type specimen of *K. lateritia* var. *prostrata* which is found in a subcluster within the second cluster together with the other *K. lateritia* var. *lateritia* specimens. The first cluster has the type specimen of *K. lateritia* var. *prostrata* and *K. lateritia* var. *lateritia*.

In the second cluster all the *K. lateritia* var. *pseudolateritia* specimens are interspersed with those of *K. lateritia* var. *lateritia* in a sub cluster consisting of the type specimen of *K. lateritia* var. *pseudolateritia* which form a major cluster with *K. lateritia* var. *lateritia* and the type specimen of *K. lateritia* var. *prostrata*. A small cluster appears to have separated from the 2 main clusters and consists of a polytomy of three *K. lateritia* var. *lateritia* OTUs. No clear internal structure can be recognized in the two dendrograms which agrees with the PCA results (Figure 4.5 and 4.6) in which the morphologically varied entities forming the *K. lateritia* complexes are not distinctly separated. Figure 4.7 shows the dendrogram obtained from cluster analysis done using nearest neighbour approach based on Jukes Cantor distance ($p>0.75$).

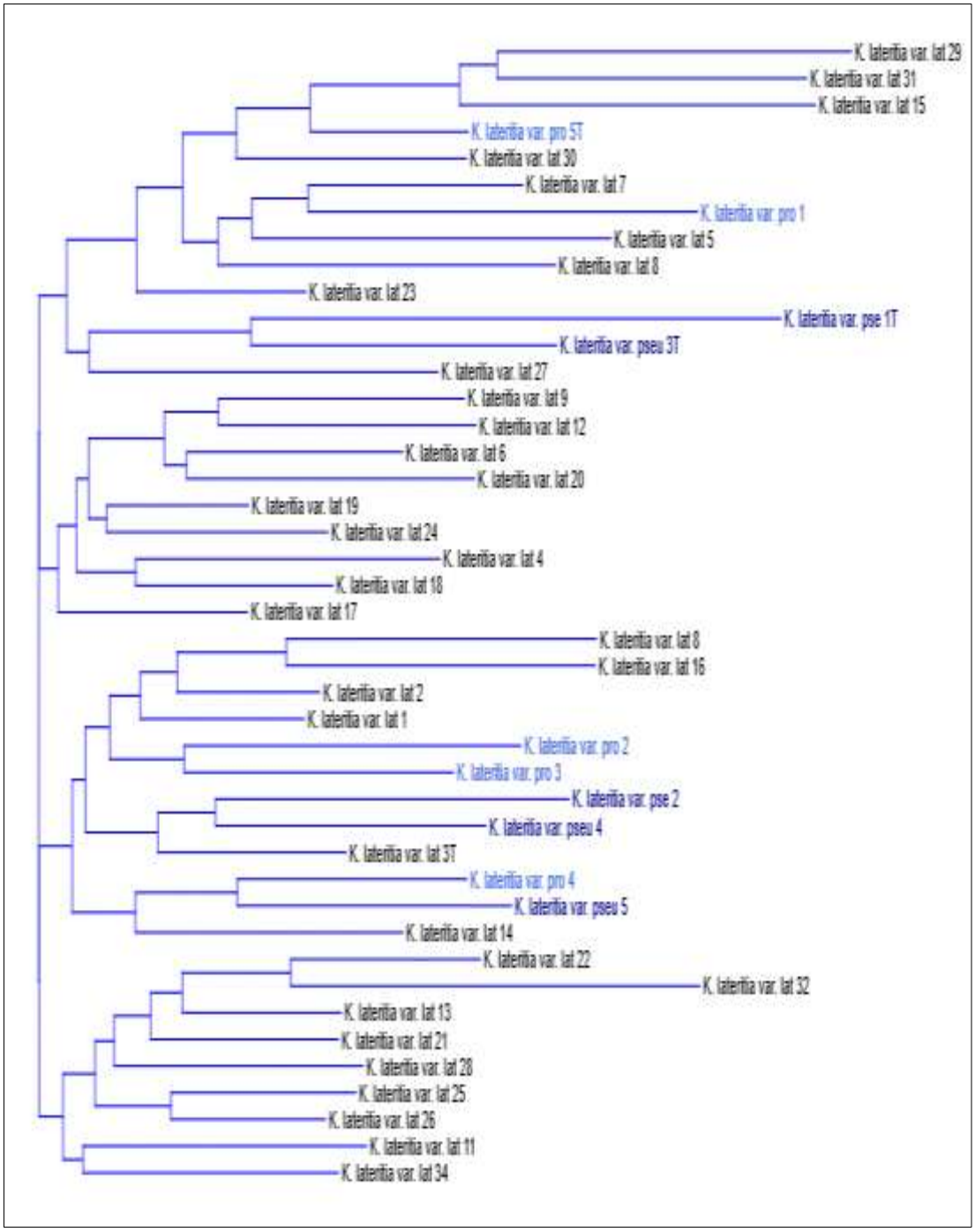

Figure 4.7. Phenogram From Cluster Analysis (UPGMA) of the *K. lateritia* var. *lateritia, K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia*.

The dendrogram in Figure 4.7 represents the clustering of *K. lateritia* accessions, encompassing various morphological characteristics of its varieties. A total of 42 accessions were analyzed, and these formed several distinct clusters. The clustering shows that *K. lateritia* var. *lateritia* accessions are distributed throughout the dendrogram. Several accessions, such as *K. lateritia* var. *lateritia* 29, 31, and 15, formed a tight cluster, whereas others such as *K. lateritia* var. *lateritia* 34 and 11 formed distinct, separate lineages.

The dendrogram also displays incomplete separation between the *K. lateritia* varieties as some overlaps in clustering were observed. For instance, *K. lateritia* var. *prostrata* 3 and *K. lateritia* var. *prostrata* 2 clustered together but separated from the type specimen within the subclades. Similarly, *K. lateritia* var. *pseudolateritia* 4 and *K. lateritia* var. *pseudolateritia* 2 but also separated from the type within the minor clades.

Notably, *K. lateritia* var. *lateritia* 14 and *K. lateritia* var. *lateritia* 3T clustered with some *K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* accessions.

4.1.1.3 Univariate Analysis

Box plots done for some of the vegetative and floral characters used in the multivariate analysis which had somewhat higher loadings in the PCA analysis and were among those used in morphological characterisation are shown in Figure 4.8A-F.

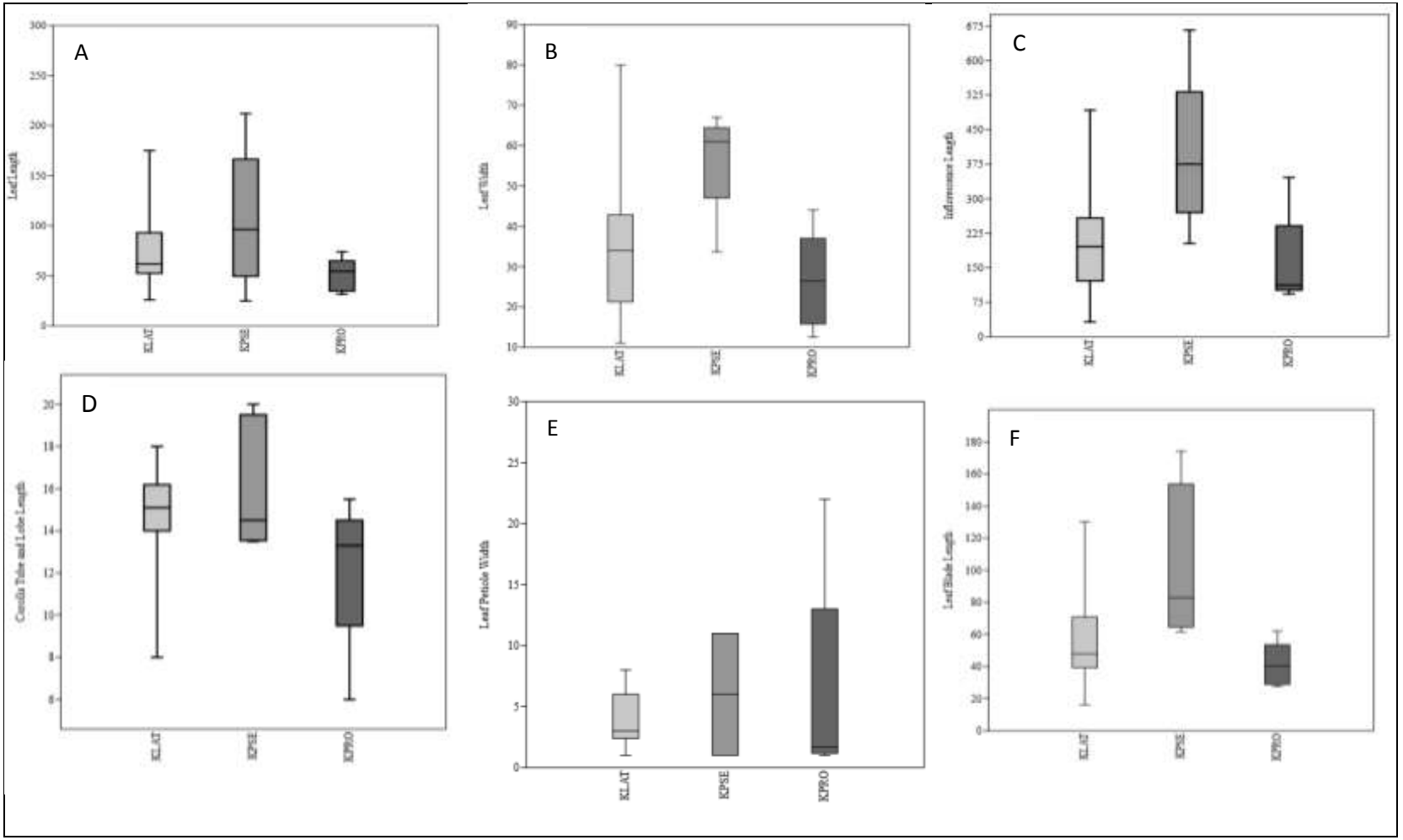

Figure 4.8. Box Plots of Selected Leaf and Floral Characters for *K. lateritia* complex (KLAT– *K. lateritia* var. *lateritia*, KPRO– *K. lateritia* var. *prostrata*, KPSE– *K. lateritia* var. *pseudolateritia*). Middle point – Mean, Box Value – Mean ± SD, Whisker value – Mean ±*SD.

From Figure 4.8, most of the characters did not show informative variation among the OTUs.

4.1.2 Morphometric Analyses of *K. nyikae* Complex

Principal Component Analysis (PCA), Cluster Analysis (CA and Univariate Analysis (UA) analyses done on the *K. nyikae* species provided invaluable information on the subspecies taxonomic relationship.

4.1.2.1 Principal Component Analysis of the *K. nyikae* Complex

Principal Component Analysis done with 21 OTU's representing subspecies of *K. nyikae* complex viz., *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* using all the 55 character states did not reveal clearly distinctive clusters as well (Figure 4.9 and 4.10). Principal Component Analysis (PCA) was carried out to examine the morphological variation between the two subspecies. The Kaiser-Meyer-Olkin (KMO) value of 0.866 was obtained indicates that the data was highly suitable for factor analysis, falling into the "meritorious" category. Meaning that the variables are well correlated hence supporting factor extraction. The analysis yielded twenty principal components, with the first three explaining a cumulative 97.42% of the total variation (Table 4.2). Principal Component 1 (PC1) accounted for the highest proportion of the variance at 73.71%, followed by PC2 at 20.67%, and PC3 at 3.04%. Table 4.2 shows the percentage variance among the OTU's along the first three components.

Table 4.2. Eigenvalues and % Variance for *K. nyikae* Species Complex.

PC	Eigenvalue	% Variance
1	9384.01	73.71
2	2630.99	20.67
3	387.346	3.04

Figure 4.9 and 4.10 show the scatter plots for the distribution of the *K. nyikae* species OTU's in the multivariate space.

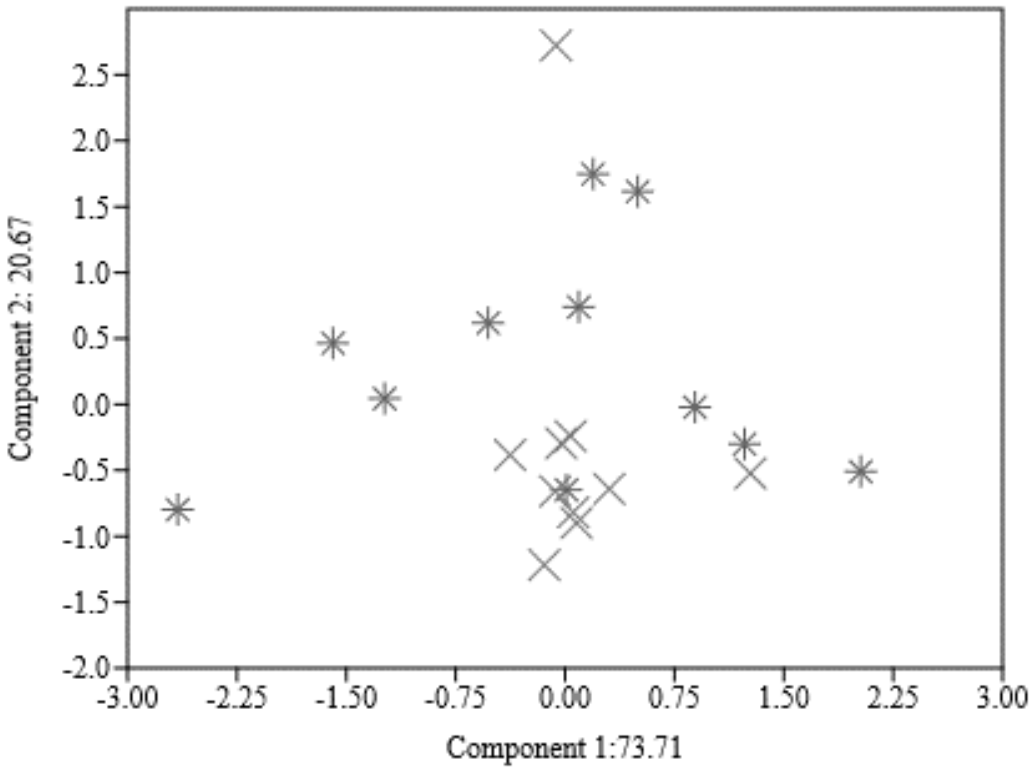

Figure 4.9. Scatter Plots of the 21 OTU's Plotted Against the First Component-Plane by the Second Component-plane for *K. nyikae* Species Complex. *Kalanchoe nyikae* subsp. *auriculata* (*) and *K. nyikae* subsp. *nyikae* (X).

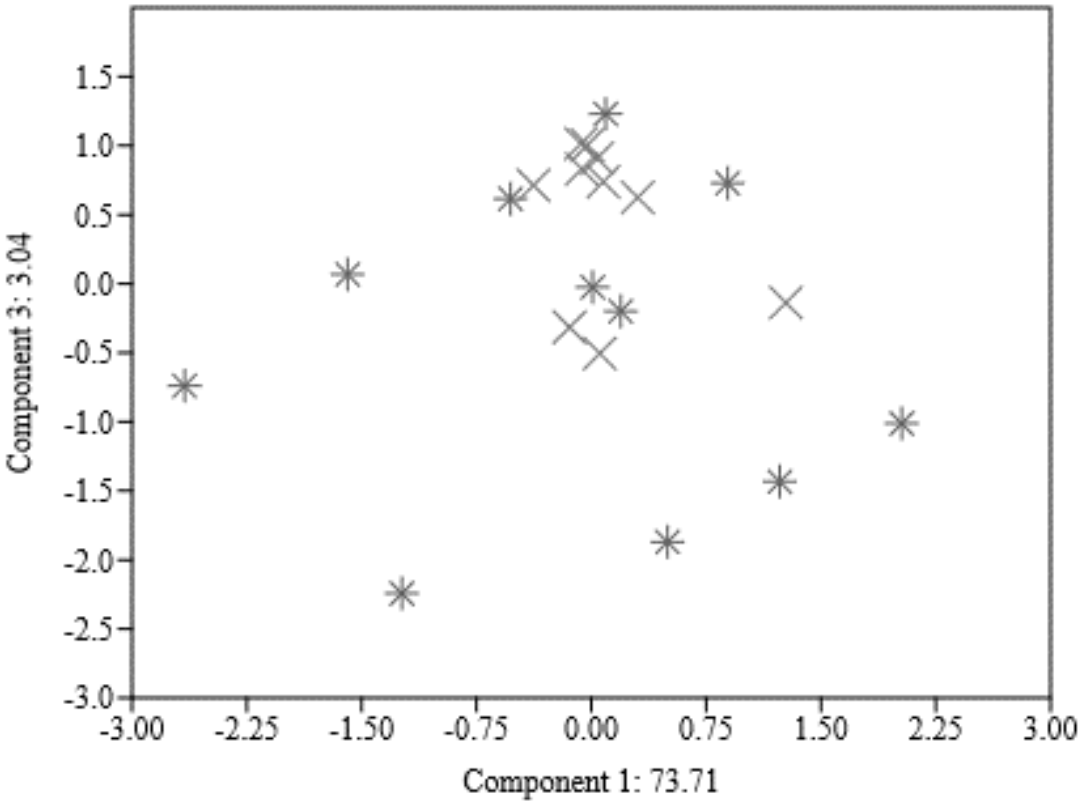

Figure 4.10. Scatter Plots of the 21 OTU's Plotted Against the First Component-Plane by the Third Component-plane for *K. nyikae* species Complex. *Kalanchoe nyikae* subsp. *auriculata* (*) and *K. nyikae* subsp. *nyikae* (X).

In the scatter plot of PC1 against PC2 (Figure 4.9), a partial separation of the two subspecies was observed. Individuals belonging to *K. nyikae* subsp. *auriculata* (*), exhibited a wider spread along the PC1 axis. In contrast, *K. nyikae* subsp. *nyikae* (X), formed a more compact cluster concentrated towards the center of the plot.

The PC1 versus PC3 (Figure 4.10) plot showed a similar, albeit less pronounced, trend. While PC3 explained a relatively small proportion of the variation, it contributed to a modest vertical separation between individuals, enhancing the overall visualization of

differentiation. Examination of the component loadings revealed that PC1 was primarily influenced by inflorescence length (IL), with a high loading of 0.98, followed by smaller contributions from leaf length (LL) and leaf blade length (LBL)**.** The second PC, was strongly influenced by leaf length (LL), leaf blade length (LBL), and leaf width (LW), with loadings of 0.65, 0.58, and 0.41 respectively.

The third PC, although accounting for only a small percentage of the variation, was defined by strong loadings on leaf petiole length (LPL) and leaf width (LW), with values of 0.63 and 0.58 respectively. As observed in the previous PCA results on *K. lateritia*, no distinct groups of the two subspecies of *K. nyikae* along all the components were seen in the multivariate space. *Kalanchoe nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* were intermingled within the space along all the components (See Figure 4.9 and 4.10). However, *K. nyikae* subsp. *auriculata* OTUs are more clustered to the right and upper part along the first and third components respectively.

4.1.2.2 Cluster Analysis of *K. nyikae* Complex

Cluster Analysis of 21 OTU's of *K. nyikae* done using Euclidean distance revealed no distinct clusters of the two subspecies of *K. nyikae* in the dendrogram space (Figure 4.11). *Kalanchoe nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* were intermingled within the subclades within the main clade. No clear cluster of any of the subspecies of *K. nyikae* can be identified in the small clusters. Figure 4.11 shows the dendrograms obtained from cluster analysis done using nearest neighbour approach based on Euclidean.

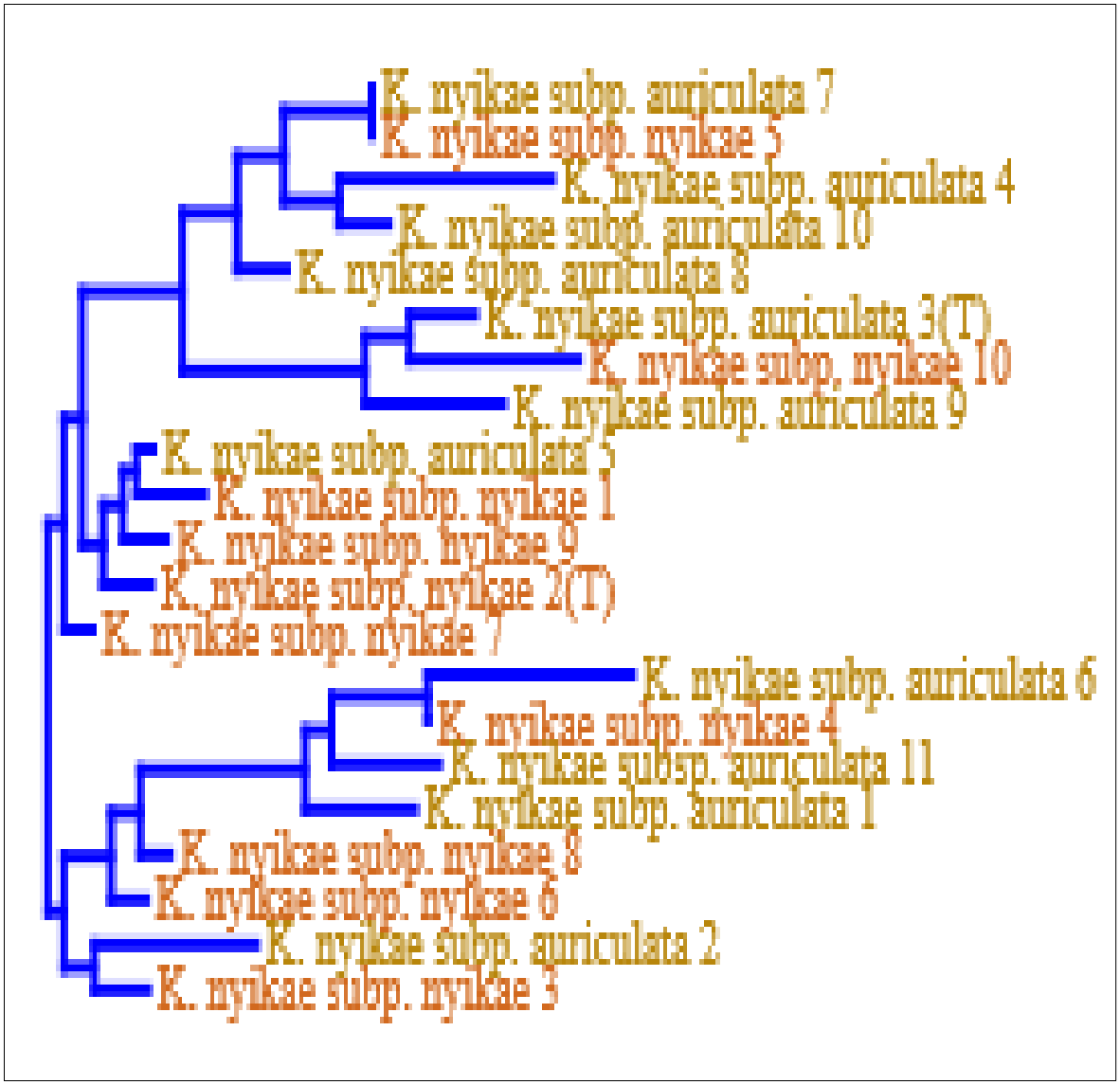

Figure 4.11. Dendrogram From Cluster Analysis (UPGMA) for *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae*.

In Figure 4.11, three sub-clusters can be seen, all comprising the OTUs representing the two subspecies of *K. nyikae* intermixed in almost equal proportions. The overall pattern shows partial intermixing between the two taxa. Specimens labelled as *K. nyikae* subsp.

auriculata were distributed across several clusters rather than forming a single, coherent group. Some *K. auriculata* OTU's appeared intermixed with *K. nyikae* specimens. Similarly, *K. nyikae* OTU's clustered closely with members of *K. auriculata*. Although certain clusters contain a majority of either *K. nyikae* or *K. nyikae* subsp. *auriculata*, there is a lack of exclusive clades for each taxon.

4.1.2.3 Univariate analysis

Box plots done for some of the vegetative and floral characters used in the multivariate analysis are displayed in Figure 4.12A-F.

From the figure most of the characters that were used in morphometric analysis did not vary among the two subspecies of *K. nyikae* including those that had high factor loadings in the PCA analysis.

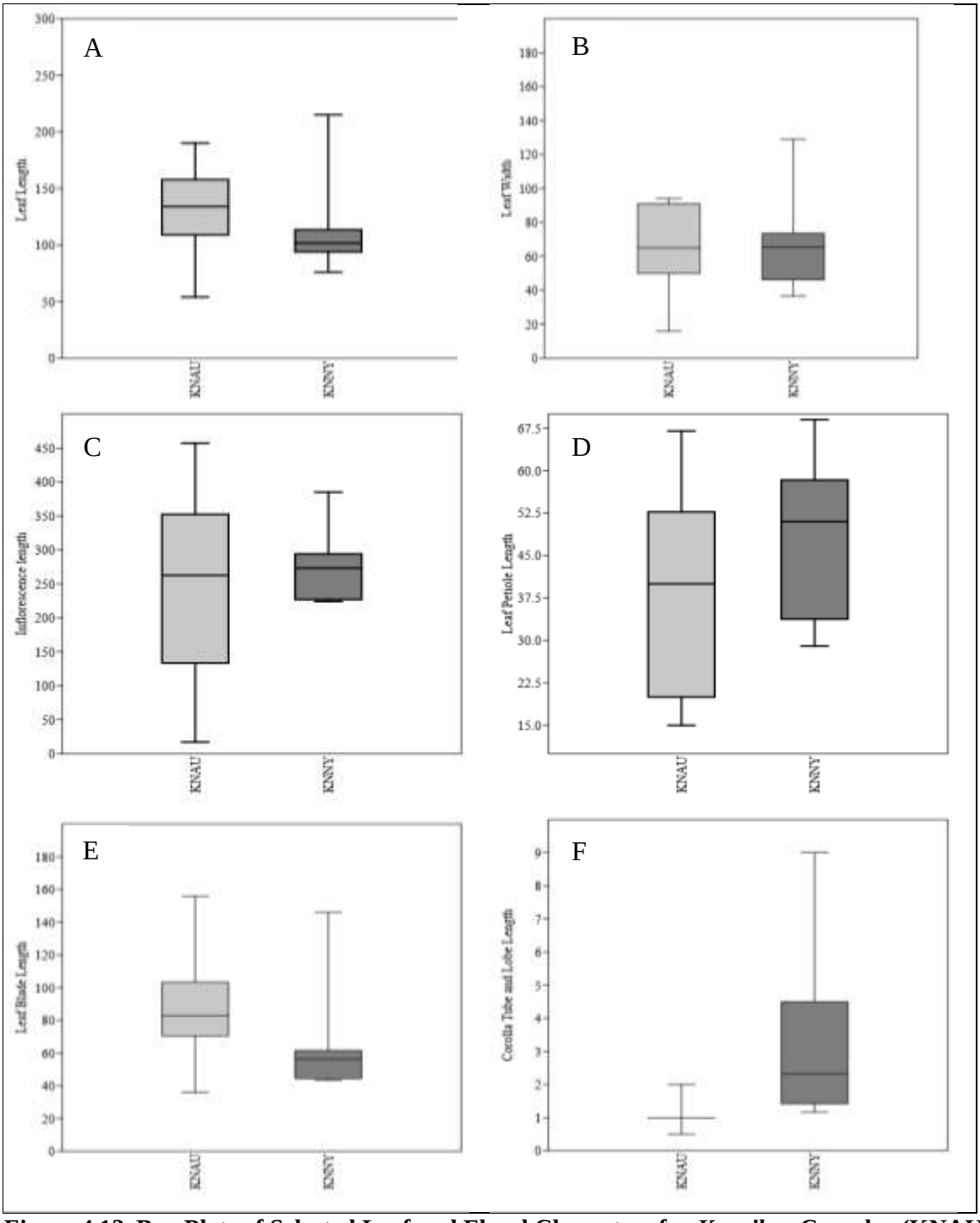

Figure 4.12. Box Plots of Selected Leaf and Floral Characters for *K. nyikae* Complex (KNAU– *K. nyikae* subsp. *nyikae*, KNNY– *K. nyikae* subsp. *nyikae*). Middle Point – Mean, Box Value – Mean ± SD, Whisker Value – Mean ±*SD.

4.2 Phylogenetic Relationships Among *Kalanchoe* Species

This section presents the results for the molecular phylogeny of *Kalanchoe* species in Kenya with emphasis on the *K. lateritia* and *K. nyikae* infraspecific boundaries.

4.2.1 General Overview and the Position of the *Kalanchoe* Species in the Phylogenetic Tree

Phylogenetic relationships among *Kalanchoe* species are illustrated in ASTRAL phylogenetic tree (Figure 4.13) and ML tree (Figure 4.14) obtained in this study. The ASTRAL phylogenetic tree (Figure 4.13) revealed two main clades with one basal outlier (From Madagascar), basal sister to a clade that consisted of Malagasy taxa. Clade 1 consisted of Malagasy taxa 00while clade 2 had the rest of the African as well as the Asian and Arabian taxa. The second clade had six subclades (I– VI). One of the outlier taxon, *K. linearifolia* Drake (Local Posterior Probability (LPP-1)), a taxon from Madagascar in the subgenus *Kalanchoe* is sister to the rest of *Kalanchoe* taxa that were sampled, with support (LPP-1). It forms the most basal node on the phylogenetic tree as a single entity in both the ASTRAL and ML trees obtained from the sequence data. Some nodes in the tree remained unsupported; these are noted in the discussion below. Figure 4.13 displays a phylogenetic tree that provides insights into the evolutionary relationships among the 19 *Kalanchoe* species found in Kenya. By analyzing their clustering patterns, bootstrap support, and branch lengths, genetic relatedness and taxonomic classification can be inferred.

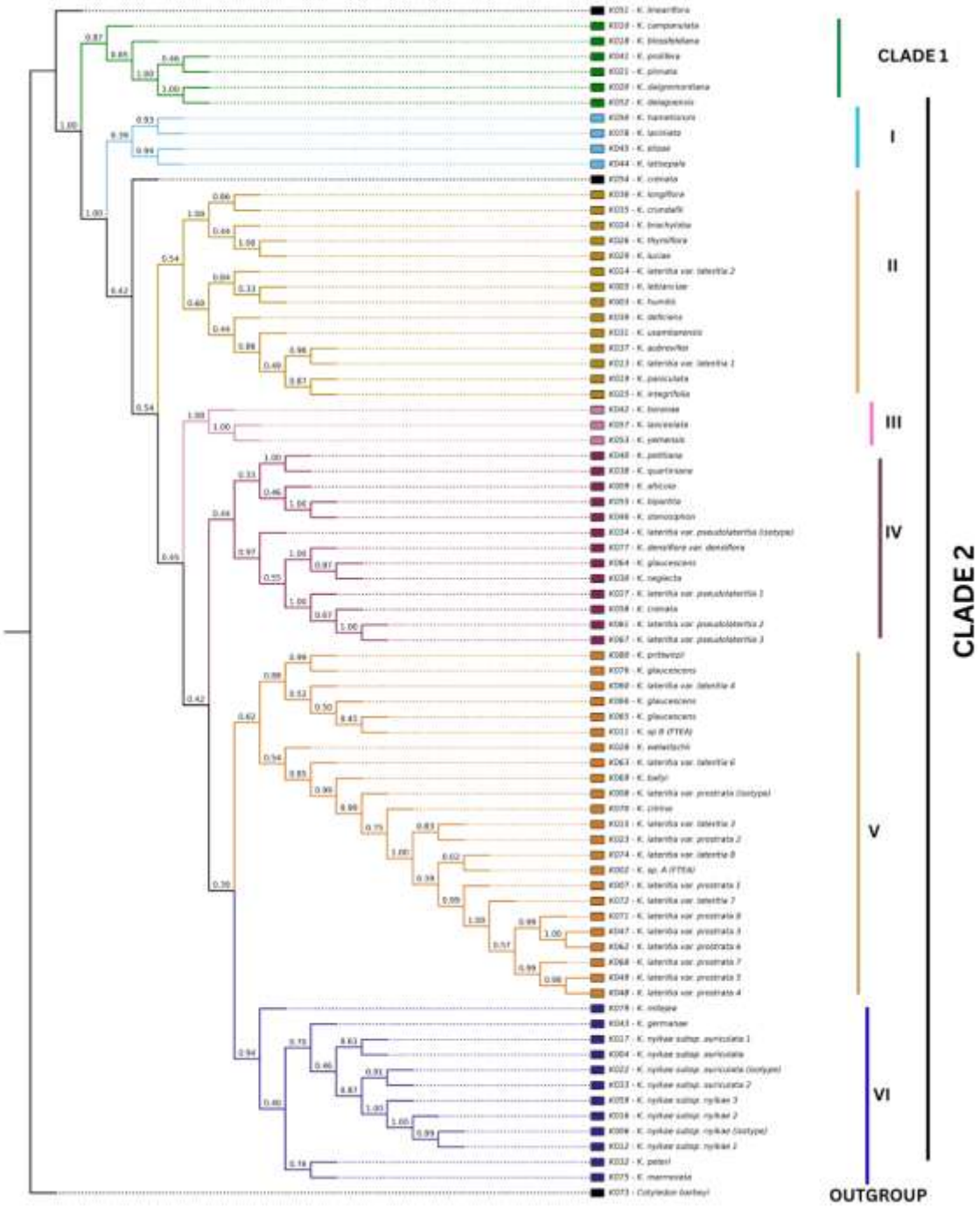

Figure 4.13. ASTRAL Phylogenetic Tree Obtained From DNA Sequence Data Gathered Using Target Sequence Capture Using the Angiosperms - 353 Probe Set Analysed Using the Maximum Likelihood Criterion for 80 *Kalanchoe* species From Africa, Asia and Madagascar.

The most basal clade after the nodes of the basal outlier entity of *Kalanchoe* consisted of Malagasy taxa (clade 1) that separated from the monophyletic clade of the mostly African, a few Asian and Arabian *Kalanchoe* taxa (clade 2) with support (LPP- 0.85). *Kalanchoe pinnata* and *K. delagoensis*, Malagasy natives which have been introduced in Kenya fitted well in the Malagasy taxa clade. *Kalanchoe campanulata* (Baker) Baill. is supported (LPP-0.85) as a sister to the rest of the Malagasy taxa within the clade. *Kalanchoe prolifera* and *K. pinnata* were not supported as sisters and formed a sister group to *K. daigremontiana* and *K. delagoensis*, which were supported as sisters. *Kalanchoe blossfeldiana* is a sister to four taxa within the Malagasy clade.

The African, Asian and Arabian taxa formed a monophyletic group (clade 2) with six subclades subtending strongly supported relationships at the tips. The first subclade was not supported at the node but strongly supported at the tips. The monophyletic group consisted of taxa from Mozambique viz., *K. hametiorum* Raym.-Hamet, *K. elizae* A. Berger and *K. latisepala* N.E. Br. that were strongly supported as sisters (0.93). *Kalanchoe hametiorum* and the widely distributed Kenyan taxon, *K. laciniata* formed a sister group within the subclade. *Kalanchoe laciniata* was the second Kenyan taxa to diversify after *K. pinnata* that clustered together with other *Bryophyllum* taxa from Madagascar in the tree.

Within the second clade *K. crenata* from Loita hills was weakly supported as a sister to the rest of the taxa in the remaining five subclades. The second subclade, though not supported, consisted mainly of southern Africa taxa and a few from Asia, Saudi Arabia,

Yemen and Madagascar. Within the clade we had the Kenyan widely distributed, *K. lateritia* var. *lateritia* and endemic, *K. aubrevillei*. Within the same clade was *K. usambarensis* Engl. and Raym.-Hamet, a Tanzanian endemic and widely distributed *K. humilis* Britten (Tanzania, Malawi and Mozambique), *K. paniculata* Harv. (Botswana, South Africa, Mozambique), *K. deficiens* (Forssk.) Asch. and Schweinf. (Saudi Arabia and Yemen) and *K. integrifolia* Baker from Madagascar as a sister to *K. paniculata* within the minor clade.

Within this subclade, there were two main groups with the first one being strongly (LPP-1) supported as a group of only southern African taxa. This group was a sister to another group that also separated into two sister groups. The first group consisted of two species with southern Africa origin *K. leblanciae* Raym.-Hamet and *K. humilis* and *K. lateritia* var. *lateritia* from Tanzania. The second small cluster had *K. deficiens* strongly supported as a sister to *K. aubrevillei* and *K. lateritia* var. *lateritia* as close sisters to *K. paniculata* from South Africa (Botswana, South Africa and Mozambique) and *K. integrifolia* from Madagascar. The only Kenyan species in the larger second subclade were *K. aubrevillei* and *K. lateritia* var. *lateritia*.

The third subclade which was not supported at the node was supported at the tips with *K. boranae*, a Kenyan endemic species being strongly supported (1.00) as a sister to *K. yemensis* (Deflers) Schweinf. from Yemen and the annual *K. lanceolata* that has a wider distribution in Uganda, Kenya, Tanzania, West Africa from Guinea to Cameroon eastwards

to Ethiopia and Somalia, Zaire, Malawi, Mozambique, Zambia, Zimbabwe, Angola, Namibia, South Africa, Madagascar, Arabia and Asia.

The fourth subclade recovered in the analysis was not supported at the nodes but supported at the tips just like most African *Kalanchoe* taxa clades. The group consists of taxa distributed in Ethiopia, Eritrea, South Africa, Mozambique, Swaziland, Kenya and Tanzania. The subclade subdivides into two other sister clades. The first minor subclade within subclade 4 is not supported and consists of species from Ethiopia, *K. petitiana* A. Rich and *K. quartiniana* A. Rich strongly supported (1.00) as sister taxa, and a sister group to a clade consisting of *K. bipartita*, a Kenyan and Somalia endemic, *K. stenosiphon* Britten from Ethiopia and Eritrea and *K. alticola* Compton from Swaziland. *Kalanchoe alticola* is strongly supported (1.00) as a sister to two close sister taxa, *K. bipartita* and *K. stenosiphon*.

The second minor subclade within subclade 4 which was supported (0.97) had *K. lateritia* var. *pseudolateritia* a Kenyan and Tanzanian endemic, together with its isotype and close allies like *K. crenata*. The *K. lateritia* var. *pseudolateritia* (isotype) is strongly supported as a sister to two smaller sister groups consisting of *K. densiflora* var. *densiflora*, widely distributed in Ethiopia, Kenya, Sudan (Imatongs), Tanzania, Uganda and Zaire (Ruwenzori), *K. glaucescens* which is distributed in Arabia, Burundi, Ethiopia, Kenya, Uganda, Rwanda, Sudan, Somalia, Tanzania and Zaire and *K. neglacta* Toelken from South Africa and Mozambique (POWO, 2025). The two Kenyan sister taxa overlap in their distribution in Ethiopia, East Africa, Zaire, Sudan and have a tendency of hybridizing.

The fifth subclade which was not supported and paraphyletic had two minor subclades comprising taxa from eastern, central and southern Africa. Most of the Kenyan taxa sampled were also in this clade. The subclade included the unidentified *K.* sp. A (*FTEA*) species that is endemic to Tanzania, *K.* sp. B (*FTEA*) that is endemic to Kenya and Tanzania and the isotype of *K. lateritia* var. *prostrata* that has its distribution in Kenya and Tanzania only. It also had *K. welwitschii* Britten from Angola and southern Africa. The subclade has two minor subclades both with a noticeably higher percentage of Kenyan *Kalanchoe* taxa sampled. The first minor subclade within the fifth subclade was supported (0.88) and consisted of *K. prittwitzii* and *K. glaucescens* as close sisters with support (0.99) and as sisters to *K. lateritia* var. *lateritia* and *K.* sp. B (*FTEA*). *Kalanchoe prittwitzii* is widely distributed in Uganda, Kenya, Tanzania, Zaire, Sudan, Ethiopia and Somalia. Its distribution overlaps with the distribution of *K. glaucescens* in Zaire, Sudan, Ethiopia and Somalia and with that of *K. lateritia* var. *lateritia* in Zaire and Rwanda. The three species might have had a similar origin and diversification.

The second minor clade within the fifth subclade that was moderately supported consisted of *K. welwitschii* as sister to the rest of the taxa within the clade with support (0.85). *Kalanchoe lateritia* var. *lateritia*, *K. lateritia* var. *prostrata* (type specimen), *K. ballyi* a Kenyan coast endemic and *K. citrina* were supported as independent sisters to *K. lateritia* var. *lateritia*, *K. lateritia* var. *prostrata* and the unidentified species *K.* sp. A (FTEA).

The (sixth) subclade was supported (0.94) and consisted of species that are mainly distributed in East Africa particularly Kenya and Tanzania. *Kalanchoe mitejea* was not

supported as a sister to a group comprising two minor subclades. The first minor subclade consisted of only two taxa that were not supported as sisters, *K. marmorata* that is distributed in Uganda, Kenya, Tanzania, Zaire, Rwanda, Sudan, Ethiopia and Somalia and *K. peteri* that is endemic to Tanzania.

The second minor subclade within the sixth subclade that was not supported (0.76) had *K. germanae* weakly supported as sister to the subminor subclade consisting of *K. nyikae* subsp. *auriculata* together with its isotype supported (1.00) sister to *K. nyikae* subsp. *nyikae* together with its isotype. The six taxa in the last clade are the most recent descendants of *Kalanchoe*. Maximum likelihood tree also revealed phylogenetic relationships among the *Kalanchoe* species sampled but they were less informative (see Figure 4.14). All the clades that had LPP of less than 0.7 were collapsed for clarity.

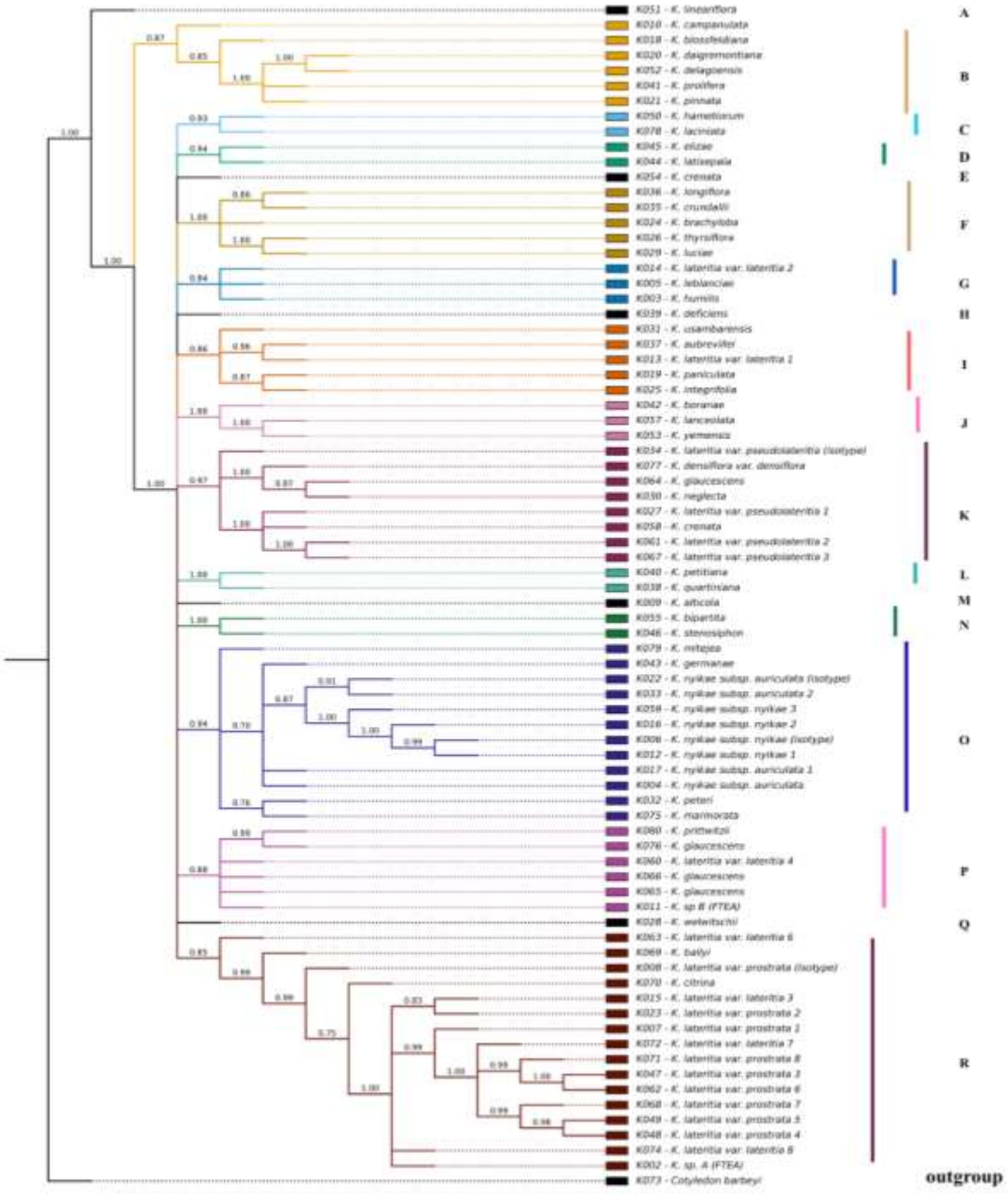

Figure 4.14. ML Tree of *Kalanchoe* taxa used in the molecular studies based on Angiosperm 353 probe kits (the different colours show the different clades)

In the ML tree *K. linearifolia* from Madagascar was a sister to the rest of the species that were sampled with support (91). Malagasy species formed a basal sister clade which separated from the species from Africa, Asia and Arabia with no support (76). The clade consisted of *K. campanulata* as a supported sister (97) to two supported sister groups, *K. delagoensis* and *K. daigremontiana* (97) and *K. prolifera* and *K. pinnata* (99).

Among the African *Kalanchoe* species there were no supported clades (76) with four main subclades. Within the first subclade, *K. neglecta* was a sister to two minor subclades with no support. The first minor clade consisted of *K. hametiorum* as a weakly supported sister to *K. boranae* which was a supported (84) sister to two supported sister taxa, *K. prittwitzii* and *K. marmorata* (100). In the second minor clade which was fairly supported, *K. glaucescens* was not supported as a sister to *K. deficiens* and *K. lateritia* var. *lateritia*. The unsupported second subclade had three minor subclades.

The first minor subclade with no support had *K. nyikae* subsp. *auriculata* as a sister to *K. quartiniana* (62) which was sister to two supported (100) sisters, *K. integrifolia* and *K. paniculata*. In the second minor subclade (70) there were two minor clades with *K. densiflora* var. *densiflora* as a close sister to *K. glaucescens* (100) emphasising their sister relationship in the ASTRAL tree. The two were not supported as sisters to *K. yemensis* (68), and three weakly supported Kenyan sister taxa, *K. nyikae*, *K. lateritia* var. *prostrata* and *K. lanceolata*. The second minor subminor clade was not supported (78) as a sister clade to the third minor subclade that comprised Kenyan taxa supported as sisters. *Kalanchoe laciniata* (80), *K. glaucescens* (81) and *K. citrina* (83), were supported as close

sisters to a sister group comprising two varieties of *K. lateritia* viz., *K. lateritia* var. *prostrata* and *K. lateritia* var. *lateritia* (83) which clustered together in the multivariate space in the PCA analysis as strongly supported sisters.

The third subclade (77) had *K. crenata* as sister (74) to the rest of the taxa forming two minor subclades within it. First minor clade (60) consisted of two sub-minor clades, one with *K. mitejea* and *K. peteri* as non-supported sisters and the other one (79) with *K. crenata* (79) as a fairly supported sister to *K. lateritia* var. *pseudolateritia*. The second minor clade (63) consisted of *K. petitiana* weakly supported (43) as a sister to taxa forming two sub-minor clades one consisting of *K. nyikae* subsp. *nyikae* (95) and the other one with *K. luciae* (86) as a sister *K. crundallii* I. Verd. (80) and close sisters *K. aubrevillei* and *K. brachyloba* Welw. ex Britten (80).

The fourth clade consisted of many species diverging at different times with *K. lateritia* var. *pseudolateritia*, K. sp. A (*FTEA*) and *K. bipartita* as close sisters in one of the minor subclades. *K. lateritia* var. *pseudolateritia* (isotype), K. sp. B (*FTEA*) and *K. nyikae* subsp. *nyikae* (isotype) were also close sisters within another subminor clade. All the *K. nyikae* subsp. *auriculata* taxa forms another supported (86) sub-minor clade together with its isotype. *K. lateritia* var. *prostrata* (isotype) is not supported as a sister to a minor clade comprising *K. usambarensis*, *K. germanae*, *K. lateritia* var. *lateritia*, *K. pinnata* and *K. nyikae* subsp. *nyikae*. The last clade consisted of almost all the type specimens that were sampled.

4.2.2. Phylogenetic Relationships Among Different *Kalanchoe* Species in Kenya

The phylogenetic analysis of Kenyan *Kalanchoe* species reveals a complex pattern of evolutionary relationships, characterized by the distribution of the species in Kenya across multiple well-defined clades. Closely related species tend to form tight clusters, reflected by short branch lengths, while more distantly related taxa exhibit greater genetic separation, as shown by longer branches. Some species cluster together within the same or nearby clades while others are in distant clades. Species in the same or nearby clades include *K. bipartita, K. crenata, K. densiflora* and *K. lanceolata* in one subclade while *K. ballyi, K. boranae, K. fadeniorum, K. nyikae* in another subclade. *Kalanchoe lateritia, K. citrina* and *K. marmorata* are in different subclades but within the broader *Kalanchoe* clade. *Kalanchoe glaucescens* and *K. mitejea* form separate lineages within the *Kalanchoe* clade. *Kalanchoe obtusa* and *K. laciniata* are in different subclades. Within the phylogeny, certain species demonstrate particularly close relationships. *Kalanchoe ballyi* and *K. bipartita*, for instance, appear within the same clade. Similarly, *K. crenata* and *K. densiflora* cluster together. Another clearly defined grouping includes *K. lateritia* and *K. nyikae*, which form robust sister subclades.

Conversely, a number of species display marked divergence from the central clusters. *Kalanchoe fadeniorum* and *K. prittwitzii* are found on relatively long branches. Likewise, *K. glaucescens* and *K. obtusa* show a more distant placement in the tree. Support for these phylogenetic relationships is provided by bootstrap analysis. Several key nodes, such as the relationship between *K. lateritia* and *K. nyikae* are backed by high bootstrap values

(≥0.85), indicating strong statistical confidence in these groupings. However, other branches exhibit lower support values (≤0.85).

4.2.3 Molecular Relationship Among Taxa in *K. lateritia* and *K. nyikae* Species Complexes

From the phylogenetic trees obtained in this study the subspecies forming the *K. nyikae* complex separated into two small sister clades in the ASTRAL tree with all the taxa sampled but remain unresolved in the ML tree. While *K. lateritia* varieties did not show a distinct relationship in the ASTRAL tree (Figure 4.13), they displayed a very informative relationship regarding the second tree that consisted of *K. lateritia* and *K. nyikae* species only (See Figure 4.14).

Just like in the ASTRAL tree, in the ML tree (Figure 4.14), *K. linearifolia* was a sister to a clade that subdivided into two main clades where Subgenera *Kitchingia* (*K. campanulata*) (A) and *Bryophyllum* (B) both from Madagascar formed one clade and subgenus *Kalanchoe* another clade (C-R) (See Figure 4.14). The subgenus *Kalanchoe* clade had several subclades (C-R), where subclades K consisted of mainly *K. lateritia* var. *pseudolateritia*, R, *K. nyikae* and Q, *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* taxa (the trend in subclade K was also observed in the mutivariate space in the PCA analysis). In the *K. nyikae* subclade Q both *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* form a single clade where two of the *K. nyikae* subsp. *auriculata* taxa form a polytomy within the clade and the rest form a sister minor subclade to *K. nyikae* subsp. *nyikae*. *Kalanchoe germanae* is also found within the clade.

Interestingly, relationships between *K. lateritia* clade are more distinct than in the first ASTRAL tree that had all the sampled taxa. *Kalanchoe lateritia* var. *pseudolateritia* separates from the other two varieties together with its isotope and forms a subclade together with *K. crenata*, *K. densiflora* var. *densiflora*, *K. glaucescens* and *K. neglecta*. The remaining two varieties clustered in the same subclade (R) together with *K. ballyi*, *K. citrina* and *K.* sp. A *FTEA*.

An analysis that was done using the *K. lateritia* and *K. nyikae* taxa together with the outgroup (*Cotyledon barbeyi* Schweinf ex Baker) (See Figure 4.14) yielded an informative pattern that supports the morphometrics results where *K. lateritia* var. *pseudolateritia* forms a separate cluster from the *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* clade. *Kalanchoe nyikae* forms a monophyletic clade where *K. nyikae* subsp. *auriculata* appears to have diversified earlier in time than *K. nyikae* subsp. *nyikae* but does not separate from it completely.

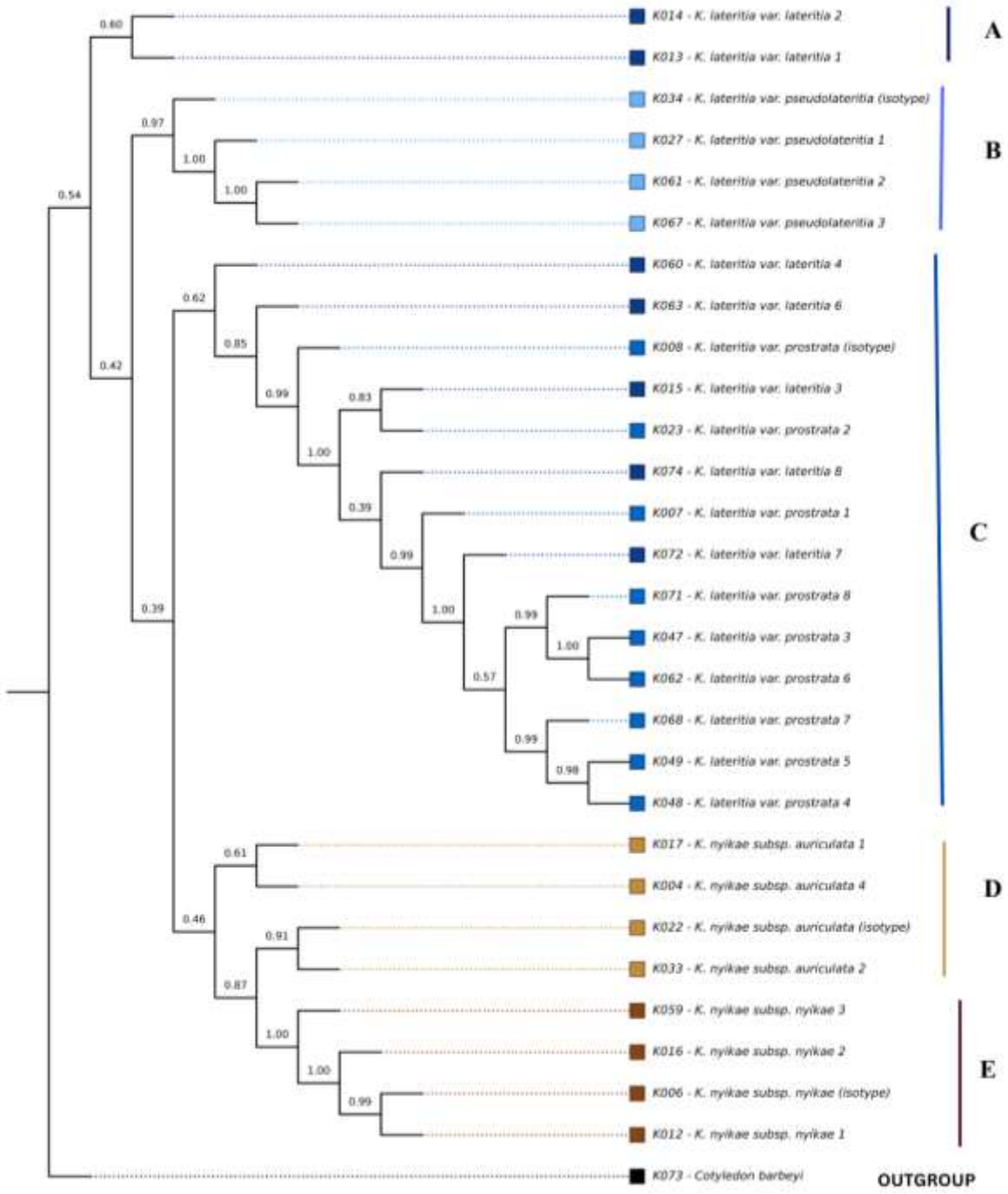

Figure 4.15. ASTRAL Phylogenetic Tree Obtained From the DNA Sequence Data Gathered Using Target Sequence Capture Using the Angiosperms - 353 Probe Set Analysed Using the Maximum Likelihood Criterion for *K. lateritia* (*K. lateritia* var. *lateritia, K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia*) and *K. nyikae* (*K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae*) Species From Africa and Asia. *Cotyledon barbeyi* was Used as anOutgroup.

The ASTRAL phylogenetic tree extracted from the main tree for the two species complexes, *K. lateritia* and *K. nyikae* displays the phylogenetic relationships among different taxa in the two complexes. *Kalanchoe lateritia* varieties form a major clade separate from *K. nyikae*. *Kalanchoe nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* form a distinct subgroup. The tree shows strong support for the clustering of *K. lateritia* var. *lateritia*, *K. lateritia* var. *pseudolateritia*, and *K. lateritia* var. *prostrata* into a monophyletic clade. Within this clade, *K. lateritia* var. *pseudolateritia* forms a distinct subgroup with high bootstrap support. *Kalanchoe lateritia* var. *prostrata* appears to be more closely related to *K. lateritia* var. *lateritia* than to *K. lateritia* var. *pseudolateritia*, as evidenced by the branch structure. *Kalanchoe nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* form a distinct subgroup. The tree strongly supports the distinction between *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae*, forming a well-supported clade separate from *K. lateritia*.

4.2.4 Comparison Between Dendrograms and Phylogenetic Trees of *K. lateritia* and *K. nyikae* Species Complexes.

The comparison of the morphological and molecular results is summarized in Table 4.3.

Table 4.3. Comparison of Phylogenetic and Morphological Findings.

Aspect	Phylogenetic Trees (Molecular Data)	Dendrograms (Morphological Data)	Agreement
Major Clades	*K. lateritia* and *K. nyikae* are distinct	Same pattern observed	Agreement
Relationship of *K. lateritia* varieties	*K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* are closely related, *K. lateritia* var. *pseudolateritia* is more distinct	Similar pattern, but more morphological overlap	Agreement with minor differences
Relationship of *K. nyikae* subspecies	subsp. *auriculata* and subsp. *nyikae* are closely related but distinct	Same clustering pattern observed	Agreement
Taxonomic Validation	Molecular data strongly supports taxonomic divisions	Morphological data shows some trait-based overlaps	Agreement but with some phenotypic plasticity
Monophyly of *K. lateritia*	Confirmed as monophyletic	Some trait-based overlaps suggest paraphyly	Mostly, but morphological data shows more variation

From Table 4.3 there was agreement between morphological and molecular results for *K. nyikae* subspecies to a larger extent as compared to *K. lateritia* except for *K. lateritia* var. *pseudolateritia*.

4.3 Ethnobotanical Studies of *Kalanchoe* Species in Kenya

This section documents the ethnobotanical uses of *Kalanchoe* species in Kenya including their localities and local names.

4.3.1 Occurrence, Uses, Ethnotaxonomy of *Kalanchoe* Species in Kenya

The ethno-taxonomic data revealed significant linguistic variation in local names for *Kalanchoe* species across various communities in Kenya, influenced by cultural practices, geographic factors, and social preferences. The study noted two divergent patterns in the

local names for *Kalanchoe* plants: names were either substantially different within a particular community and geographic area, or comparable with little variations in spelling and phonology. Among the Nilotes, the Maasai ethnic group used a distinctive naming system, where the same vernacular name, '*masilki*' is used for different *Kalanchoe* species, with a second name added to distinguish specific species. For example, they add '*ndulelei*' for *K. lanceolata* to distinguish it from *K. glaucescens* ('*masilki*'), based on functional or morphological differences between the species.

On the other hand, the Nilotes refer to *K. densiflora* and *K. lateritia* as '*bebe*' or '*tangaratwet*/*buserwet/taraqwet*' and '*yaith picho*' (Kalenjin and Luo, respectively). Whereas these species have different or near-identical names among the Kalenjins (Table 4.4), local names for *Kalanchoe* species varied according to language variations among communities interviewed in this study. The occurrence, use and other related information areshown in Table 4.4.

Table 4.4. Occurrence, Ethnotaxonomy and Uses of *Kalanchoe S*pecies in Kenya.

Scientific Name	Region / Study Sites	Ethnic Groups	Local Names	Locality Codes	Uses	Ecology / Notes
K. ballyi	Kenya (various)	—	—	K7	No recorded traditional uses.	Wild species; growth depends on rainfall.
K. citrina	Baringo, Narok, Machakos	—	—	K1, K5–K6	Stomachache medicine; antimicrobial in poultry.	Grows in rocky areas.
K. crenata	Western Kenya	Luhya-Bukusu, Luhya-Maragoli	*Namafumo*, *Rineke*	K3, K5, K7	Treats sprains, wounds, skin infections, ringworm, hernia, stomachache; blood cleanser; antiseptic soap; ornamental; poultry antimicrobial; used for aesthetic smearing of houses; culturally important for circumcision wounds.	Grows near homesteads and forests.
K. densiflora	Rift Valley, Eastern, Coast; multiple regions	Kalenjin, Kisii, Kikuyu, Maasai, Taita, Luhya-Idakho	*Taragwet*, *Kuseruwet*, *Masilgi*, *Mrizongo*, *Omoneke*, *Mugauta*	K1, K5–K6	Treats stomachache, diarrhoea, toothache, earache, swollen spleen & stomach, pain relief, rashes; poultry antibiotic; insect bite treatment; rheumatism; fuel; food; shade tree; ornamental; antiseptic; anti-inflammatory.	Widely used medicinally; grows naturally in farms; overexploited; affected by deforestation and herbicides.
K. glaucescens	Maasai areas; near homesteads	Maasai	*Masilik*	K2–K7	Ornamental.	Grows near homesteads; growth depends on rainfall.
K. lanceolata	Nationwide; homesteads	Kalenjin, Maasai, Kamba	*Kipchobos*, *Masilik ndulelei*, *Inyoeni*	K1–K7	Arthritis, sprains, skin rashes, antiseptic; ornamental.	Grows widely in rainy season; populations reduced by drought and land degradation.

Scientific Name	Region / Study Sites	Ethnic Groups	Local Names	Locality Codes	Uses	Ecology / Notes
K. laciniata	Roadside areas	—	—	K1, K4–K6	No recorded medicinal uses.	Grows on roadsides.
K. lateritia	Western, Rift, Coast	Kalenjin, Taita, Duruma	*Tangaratwet*, *Buserwet*, *Mburizongo*, *Gonzi-chireka*	K1, K4–K7	Treat stomachache, sprains, fractures, swollen spleen, rashes, cough, chest pain; used for whistles; veterinary medicine; ornamental.	Threatened by forest clearing.
K. marmorata	Narok, Kikuyu areas	Maasai, Kikuyu	*Ihuthia*, *Masilgi*	K1, K4, K6	Ornamental (graveyards, homesteads); sprains, wounds, rheumatism; massage with warm leaves.	Becoming rare due to overharvesting.
K. mitejea	Baringo, Taita; roadsides & streams	—	—	K3, K4, K6, K7	No documented medicinal uses.	Grows near streams, bushes, sometimes near beehives.
K. nyikae	Taita Taveta; Coast/Rift rocky beds	—	—	K4, K6, K7	No uses recorded.	Grows on rocky beds.
K. obtusa	Coastal Kenya (Duruma)	Duruma	*Toro*, *Komba*	K7	Ornamental; food (vegetable); bathing (antiseptic); fever; swollen leg; swollen spleen; pain-reliever.	Grows near homesteads.
K. pinnata	Roadsides	—	—	K4–K5	Swollen body massage; ornamental.	Common along roadsides.
K. prittwitzii	Western / Rift; farms, forests	Kalenjin-Pokot, Luhya-Bukusu	*Bebe*, *Namafumo*	K1–K6	Treat diarrhoea, sprains, swelling, hernia, backache; skin infections; ringworm; toothache; antiseptic bath; masks for boys; firewood; food; shade; wounds; stomach upset;	Highly valued; threatened by overexploitation and land pressure.

Scientific Name	Region / Study Sites	Ethnic Groups	Local Names	Locality Codes	Uses	Ecology / Notes
					insect bites; blood cleanser.	

Each ethnic group, Nilotes (Kalenjin, Pokot, and Maasai) and Bantu (Luhya, Kisii, Kikuyu, and Duruma), demonstrated their distinct linguistic and cultural heritage by using unique local names for *Kalanchoe*. Despite the linguistic variations, all groups recognize *Kalanchoe* species. A greater degree of linguistic uniformity was noted among some Bantu ethnic groups (Luhya and Kisii), who refer to different species of *Kalanchoe* by almost similar names ('*rineke*' and '*omuneke*', respectively), with slight phonological variation in pronunciation. Conversely, within the same community, the Kikuyus use a completely different name, '*Ihuthia*'. The Maragoli differentiate *Kalanchoe* species using either morphological characters or the presumed poisonous nature of some of the species. For instance, *K. crenata* is identified with its deep green leaves and is termed as 'male' and mainly used externally for treating injuries while *K. prittwitzii* is identified with its light green leaves and presumed to be 'female' and non-poisonous. This affects their usage where *K. prittwitzii* is additionally orally utilised for various medicinal purposes as cited by informants.

Additionally, *Kalanchoe* species hold cultural and symbolic significance in various communities in Kenya. For example, the Bukusus and Isukhas, (Luhya), refer to all *Kalanchoe* species by distinct local names, '*namafumo*' (magical plant) and "*kwa matsii*"

(plants with water), respectively. For the Bukusus, *Kalanchoe* leaves are locally used in circumcision rituals to disinfect and treat the circumcision wound. Surprisingly, the Maragoli local name for *Kalanchoe* species also refers to the male organ (‘*rinege*’, local language with slight variation in phonetics), that the Bukusus treat with the *Kalanchoe* plant leaves. In another example, *K. lateritia* and *K. obtusa* are referred to as "*Gonzi-chireka*" in the indigenous language of the Duruma people who live along the coast of Kenya.

Due to its comparable succulency of leaves and antiseptic qualities, *Kalanchoe* is mistaken for or thought to be closely related to aloes (*Aloe* spp., Asphodelaceae Juss.) in some places and even referred to by the same local name ("*tangaratwet*” among the Kalenjins). An elderly informant in Bungoma believed that the *Aloe* L. image on medicated soaps packets was for *Kalanchoe*. The two plants are distinguished primarily by *Aloe* being much more robust plants with leaves in a rosette and leaf margins being spiny and *Kalanchoe* being slender and without spines on their leaf margins. Among the Luhya community the two plant leaves are interchangeably used to decorate traditional houses smeared with cow dung or/and soil.

The study highlighted the various uses of *Kalanchoe* species across six flora regions by people of diverse cultural and ethnic backgrounds including the medicinal applications (For a summary of the field responses on the applications of *Kalanchoe* spp. in Kenya (See Appendix 3). Across the country, 19 morphologically diverse species of *Kalanchoe* occur naturally in various habitats across the seven floristic regions (Plate 4.1). These species

include *K. aubrevillei, K. ballyi, K. bipartita, K. boranae, K. citrina, K. crenata, K. densiflora, K. fadeniorum, K. glaucescens, K. laciniata, K. lanceolata, K. lateritia, K. marmorata, K. mitejea, K. ndotoensis, K. nyikae, K. obtusa, K. pinnata* and *K. prittwitzii*. Plate 4.1 shows the morphological diversity of some of the *Kalanchoe* species found in Kenya.

Plate 4.1. Morphological Diversity in *Kalanchoe* Species in Kenya (A) *K. laciniata* (B) *K. crenata* (C) *K. densiflora* (D) *K. glaucescens* (E) *K. lanceolata* (F) *K. lateritia* (G) *K. marmorata* (H) *K. prittwitzii* (Photo credits: C. Bjorå (A, C, E G); G. Evusa (B, H); T. Robinson (D, F).

During field work a hybrid between *K. lateritia* and *K. lanceolata* in Narok was found near Maasai Mara National Park Sekenani gate (See Plate 4.2) depicting the fact that *Kalanchoe* hybridizes naturally.

Plate 4.2. *Kalanchoe lateritia* x *K. lanceolata* Hybrid. Photo by Evusa G.V. Narok, 2020.

Among the respondents surveyed, 82% reported using the leaves, while 18% utilized the roots of the plant. Additionally, some respondents noted that extracts could also be prepared using the entire plant through heating. Preparation techniques for *Kalanchoe* species were diverse. Topical massage was the most frequently reported method, accounting for 50% of all species documented, while warming leaves on hot charcoal—a technique used to enhance the release of active compounds—was applied to 42.9% of the species. Crushing plant parts to obtain extracts represented 28.6%, whereas chewing and mixing leaves with other ingredients (such as oil, bananas or vegetables) were each

recorded in 21.4% of the species. Boiling or preparing decoctions was the least common method, reported in 14.3% of the species (See Table 4.5 for preparation and dosage).

Table 4.5. Part used and preparation and dosage of *Kalanchoe* Species.

Species	Plant Part Used	Preparation	Uses
K. crenata	Leaves; roots	Burn leaves on charcoal & massage; crushed leaves/roots applied; thrice daily	Sprains, antiseptic/soap, skin infections, ringworms, wounds, hernia, body cleanser, stomachache, ornamental, poultry antimicrobial, aesthetic use
K. citrina	-	-	Stomachache; poultry antimicrobial
K. densiflora	Leaves	Chewing; warmed; boiled; crushed w/ oil; rubbing; boiled w/ bananas; 1–3× daily	Stomachache, diarrhoea, toothache, earache, swelling, hernia, insect bites, poultry antibiotic, lymph nodes, worms, ornamental, skin rashes, antiseptic, cough/cold, rheumatism, sprains, musk, fuel, food, anal hygiene
K. glaucescens	Leaves	-	Ornamental
K. lanceolata	Leaves	Warm leaf massage	Arthritis, ornamental, sprains, rashes, antiseptic
K. lateritia	Leaves	Chewing; crushing; warm-leaf massage; mixed with vegetables	Stomachache; poultry medicine; antimicrobial; antifungal; sprains; fractures; spleen swelling; rashes; antiseptic; chest pain/cough; ornamental; backache; massage; toothache
K. marmorata	Leaves	Warm leaf massage; planted ornamentally	Ornamental; sprains; wounds; knee pain; rheumatism; swollen body
K. obtusa	Leaves	Crushed leaves for bathing; mixed with vegetables	Ornamental; fever; vegetable; swollen leg; swollen spleen; pain relief
K. pinnata	-	-	Swollen body massage; ornamental
K. prittwitzii	Leaves; roots	Chewing; warm-leaf massage; added to bath; woven musk; root decoction	Diarrhoea; sprains; injuries; hernia; backache; infections; ringworms; toothache; circumcision mask; firewood; shade; food; colic; swollen body; wounds; antiseptic; stomach upset; blood cleanser; insect bites

However, informants noted that young people and members of ‘modern Christian’ faith were uninterested in herbal therapy or the conservation of therapeutic herbs. The herbalists interviewed said they were no longer practising their specialty or sharing knowledge due to a lack of interest and a general decrease in demand for the same. They attributed this to the need for possession of legal documents such as licences for herbal medicine practice and trade and harassment from middlemen who take crude medicine with promise of giving money in turn but fail to honour it. Attempts to locate *K. fadeniorum*, *K. bipartita*, *K. ballyi*, *K. aubrevillei*, *K. nyikae* and *K. boranae* in known localities during this study were unsuccessful and hence utility data was not recorded for them.

This study recorded uses of thirteen species of the genus *Kalanchoe*, with nine of the species exhibiting high use values (UV greater than 0.30) namely *K. prittwitzii* (21 uses), *K. densiflora* (19 uses), *K. lateritia* (15 uses), *K. crenata* (10 uses), *K. marmorata*, *K. citrina*, *K. obtusa*, *K. pinnata* and *K. lanceolata* (see Table 4.6). Table 4.6 presents the relative importance and usage levels of *Kalanchoe* species.

Table 4.6. Ethnobotanical Importance and Usage Levels of *Kalanchoe* Species in Kenya.

Scientific Name	Total No. of informants (N)	Frequency of citation (FC/n)	No. of uses of the plant (U)	Relative Importance/Use value (UV)	Relative Frequency of Citation (RFC)	% citation	% uses
K. citrina	83	2	2	1.0	0.0	1.9	2.3
K. crenata	83	10	10	1.0	0.1	9.5	11.5
K. densiflora	83	19	19	1.0	0.2	18.1	21.8
K. glaucescens	83	5	1	0.2	0.1	4.8	1.1
K. laciniata	83	1	0	0.0	0.0	1.0	0.0
K. lanceolata	83	13	5	0.4	0.1	12.4	5.7
K. lateritia	83	16	15	0.9	0.2	15.2	17.2
K. marmorata	83	5	5	1.0	0.2	4.8	5.7
K. mitejea	83	3	0	0.0	0.0	2.9	0.0
K. nyikae	83	5	0	0.0	0.1	4.8	0.0
K. obtusa	83	4	6	1.5	0.0	3.8	6.9
K. pinnata	83	3	2	0.7	0.0	2.9	2.3
K. prittwitzii	83	13	21	1.6	0.2	12.4	24.1
Kalanchoe spp.	83	6	1	0.2	0.1	5.7	1.1

From Table 4.6, *K. densiflora* and *K. prittwitzii* exhibit high levels of utilization, as reflected in their substantial frequency of citation (FC) and relative importance/use values (UV). *Kalanchoe prittwitzii* stands out with the highest percentage of uses (24.1%) and a

UV of 1.6. In comparison, *K. densiflor*a, with a UV of 1.0, demonstrates a more balanced relationship between its frequency of citation (18.1%) and percentage of use (21.8%).

Conversely, *K. laciniata* and *K. mitejea* are less frequently cited and exhibit no recorded uses. Furthermore, *K. obtusa* and *K. pinnata* have some recorded uses, their relative frequency of citation (RFC) and UV values were relatively low. The others, such as *K. nyikae*, *K. mitejea* and *K. laciniata*, had the lowest use value, while *K. glaucescens* had a moderate use value. The most valued species of *Kalanchoe* nationally for their medicinal use, *K. densiflora* and aesthetic potential, *K. lanceolata* and *K. glaucescens* appeared to be weedy in their habitats (Narok, Naivasha and West Pokot).

The ethnobotanical uses for the thirteen species of *Kalanchoe*, categorized by application types are presented in Table 4.7. The number of species and citations for specific ailments or purposes, alongside the Informant Consensus Factor (ICF) to measure agreement among informants and the percentage citation for each category are highlighted.

Table 4.7. Ethnobotanical Use Data Analysed for Some of the *Kalanchoe* Species in Kenya.

Use categories		Nt (Number of species used for the ailment	Nur (Number of use citation for each ailment)	Informant Consensus factor (ICF)-[Nur-Nt/Nur-1]	% citation (Nur/total No. of citations x 100)
Medicine	Digestive system disorders	8	8	0	8.89
Medicine	Injuries	9	22	0.52	24.44
Medicine	Muscular-skeletal system disorder	8	11	0.3	12.22
Medicine	Blood system disorder	6	8	0.29	8.89
Medicine	Circulatory system disorder	1	1	0	1.11
Medicine	Reproductive system disorder	3	3	0	3.33
Medicine	Immune system disorders	1	1	0	1.11
Medicine	Infections	4	5	0.25	5.56
Medicine	Sensory system	2	2	0	2.22
Medicine	Skin/subcutaneous cellular tissue disorder	7	8	0.14	8.89
Medicine	Pain	9	9	0	10.00
Materials		1	1	0	1.11
Fuels		2	2	0	2.22
Social uses		2	2	0	2.22
Food (vegetable)		3	3	0	3.33
Environmental uses		4	4	0	4.44

From table 4.7, *Kalanchoe* species are applied across various medicinal and non-medicinal domains as cited by informants, following the TDWG Level 1 and 2 categories). The diseases category with the greatest informant consensus factor (ICF) (0.5), and highest

citation rate by informants (24.4%) was treating injuries (sprained/fractured limb and hand, muscle cramps and wounds) which was the most prevalent usage of practically all *Kalanchoe* species in Kenya. Infections, diseases of the musculoskeletal and circulatory systems and problems of the blood system were the other uses with an ICF of 0.3. Three uses had low ICF but comparatively noteworthy percentage citation: pain, skin/subcutaneous cellular and digestive system diseases. The remainder of the uses, however, had an ICF of 0.0 and a rather low citations percentage as visualised in Figure 4.15 A. Apart from medicinal uses, this study recorded other uses of *Kalanchoe* such as material for making whistle and masks, fuel (dry stems), social (smearing houses, circumcision), food (Mijikenda), and environmental use (ornament, hygiene) although with lower percentages (Figure 4.15 B).

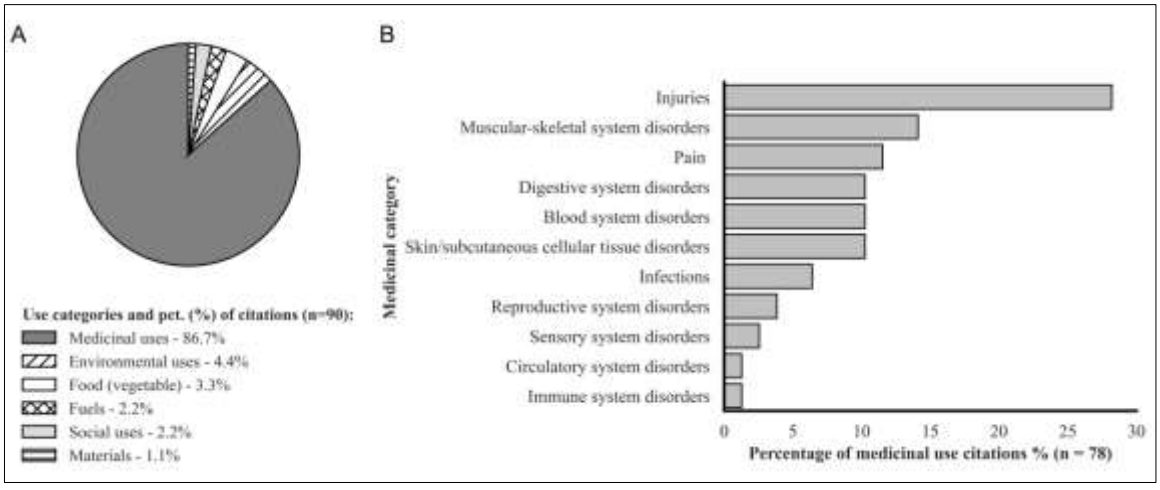

Figure 4.15. Ethnobotanical Uses of *Kalanchoe* Species in Kenya. A. TDWG Level 1 Use Categories. B. An Evaluation of TDWG Level 2 Medicinal Uses.

Environmental uses constitute 4.4% of citations. Food (vegetable) uses account for 3.3%. Fuels and social uses are both represented by 2.2% and materials by 1.1%.

4.3.2 Use of *Kalanchoe* Species in Relation to Distribution

As observed in this study, across Kenya, *Kalanchoe* species are distributed in a variety of habitats within the FTEA regions (See Figure 4.16).

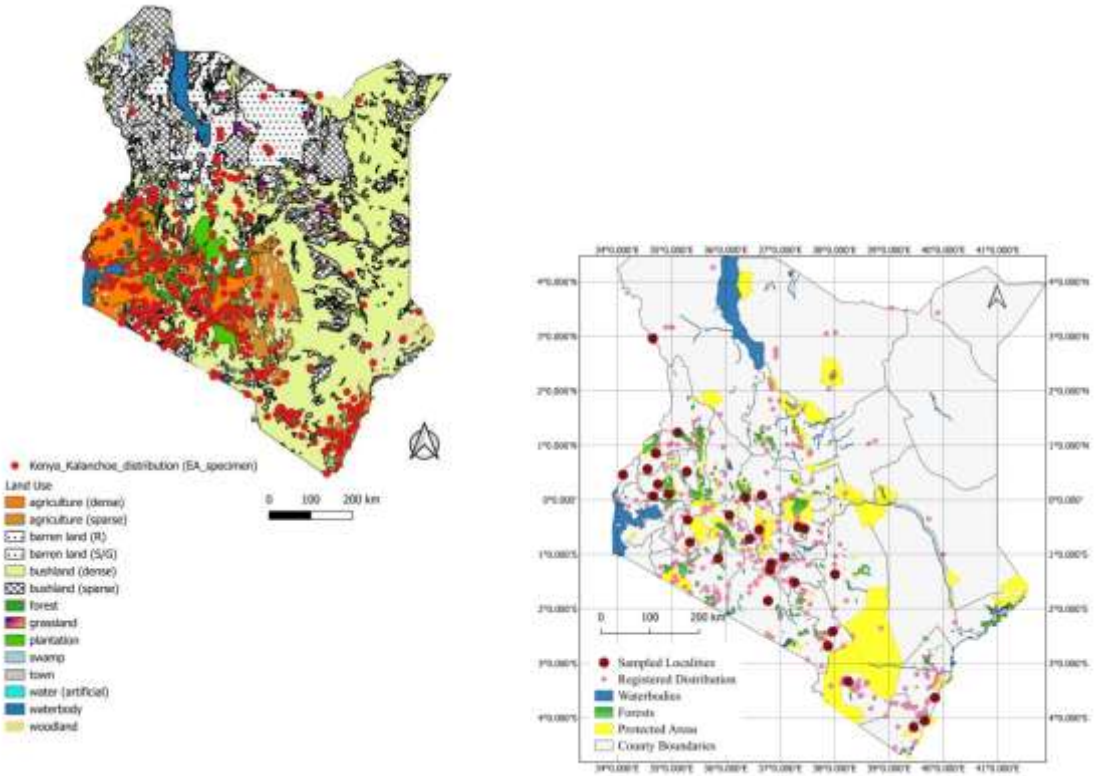

Figure 4.16. Map Showing the Distribution of *Kalanchoe* in Kenya with the collection sites highlighted

Figure 4.16, shows the distribution of the genus *Kalanchoe* in Kenya, where the 19 *Kalanchoe* species are distributed in different counties in all the seven (7) flora regions. Some species like *K. obtusa*, *K. ballyi*, *K. fadeniorum* and *K. bipartita* have restricted distribution while others like *K. lanceolata*, *K. densiflora*, *K. prittwitzii*, *K. lateritia* and *K. citrina* are more widespread and had higher citation for their application in traditional medicine. The relationship between the number of use citations, informants, and the number of *FTEA* Flora regions in which *Kalanchoe* species are distributed across Kenya is visualised in Figure 4.17.

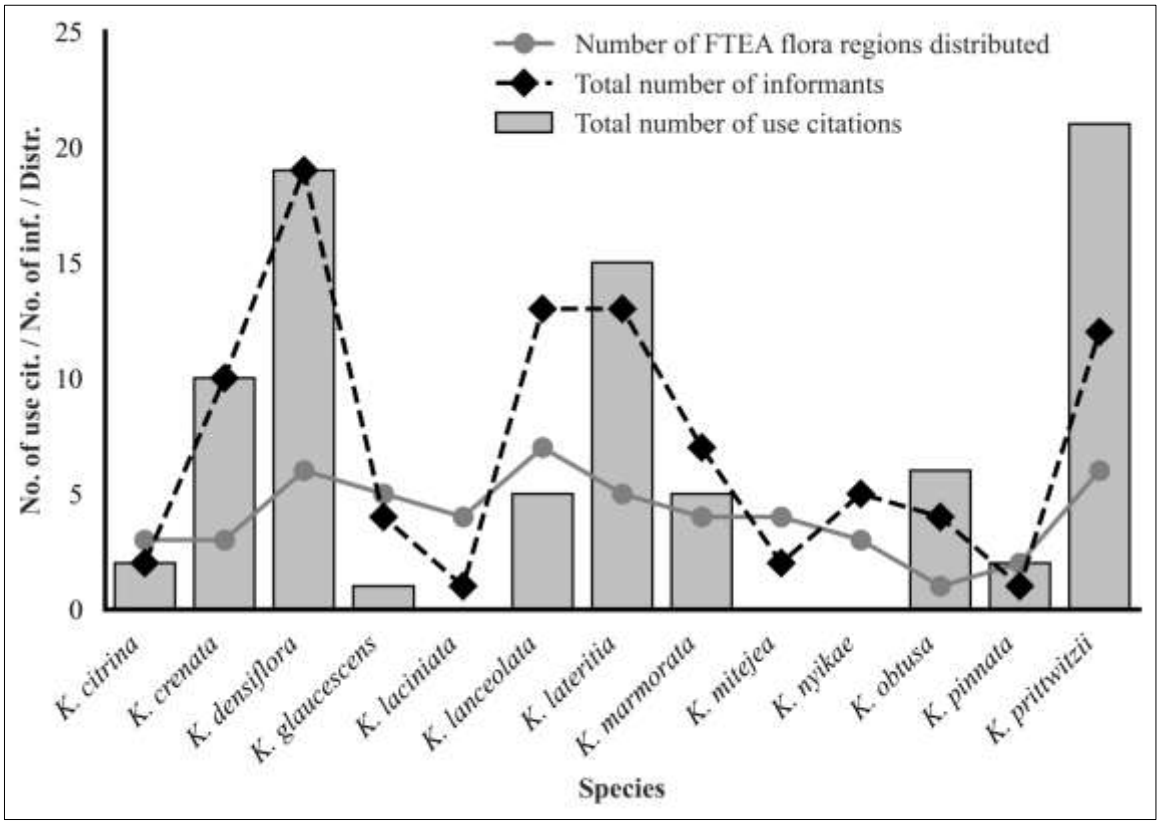

Figure 4.17. Use Records and Distribution of *Kalanchoe* in Kenya. (cit.- citation, inf.- informants, distr.- distribution).

Kalanchoe prittwitzii had the highest total number of uses (21) cited by 13 informants. Similarly, *K. densiflora* also had a high total number of uses (around 19) and informants (approximately 20). In contrast, species such as *K. citrina*, *K. glaucescens* and *K. pinnata* exhibit much lower values, with total uses ranging from 2 to 5 and informants around 3 to 5. The number of *FTEA* flora regions distributed remains relatively stable across all species, with most species being recorded in 5 to 6 regions. Species with a broader distribution across the *FTEA* flora regions, such as *K. densiflora* and *K. prittwitzii*, tend to have higher numbers of use citations and uses. In contrast, species with narrower distribution, such as *K. mitejea* and *K. laciniata*, generally exhibit fewer citations and uses. The use could also depend on the density of population where the plant is growing, for instance, *K. marmorata* in Narok.

4.4 Conservation Status of *Kalanchoe* in Kenya

This section documents the conservation status of indigenous *Kalanchoe* species in Kenya by addressing the following objectives: i. To reassess the conservation status of *Kalanchoe* species in Kenya using field studies and geographical data. ii. To exhaustively reevaluate the conservation status of *K. lateritia* and *K. nyikae*. iii. To address the gaps in the Red List status of *Kalanchoe* species in Kenya.

4.4.1 Threats as Observed and Perceived by Informants

Approximately 90% of the informants surveyed across Kenya stated that vegetation clearance for construction and agricultural practices courtesy of the growing human population pose a threat to nearly all the *Kalanchoe* (*K. densiflora*, *K. obtusa*, and *K.*

prittwitzii) and related species. Most of the plants are found growing in degraded landscapes including roadsides and rocky slopes (*K. obtusa, K. citrina, K. crenata, K. laciniata, K. lateritia, K. nyikae, K. pinnata* and *K. prittwitzii*); farms and hedges and can be uprooted when cultivating land (*K. densiflora* and *K. lanceolata*). Some grow during rainy seasons and are adversely affected by prolonged drought (*K. obtusa, K. lanceolata, K. glaucescens*). Expansion of the transport network has also affected most *Kalanchoe* habitats through quarrying and construction of roads (e.g Kolol-Toror) and other infrastructure (*K. crenata, K. lanceolata, K. prittwitzii*) charcoal making and forest fires (*K. lateritia, K. prittwitzii, K. obtusa*) e.g Chepalungu Forest. Nearly all the *Kalanchoe* species are wild with *K. crenata, K. glaucescens, K. lanceolata* and *K. prittwitzii* planted by a few people on their farms or in pots. Unique factors that could pose threat to some *Kalanchoe* species and affect their sustainable use are shown in Table 4.8.

Table 4.8. Observed and Perceived Threats to *Kalanchoe* Species in Kenya

Scientific name	Threats	Cultivation or wild
K. ballyi Raym.-Hamet ex Cufod.	Its growth depends on availability of rainfall	Wild
K. citrina Schweinf.	Grows in rocky degraded areas	Wild
K. crenata (Andrews) Haw.	Lack of indigenous knowledge about plants due to lack of interest from many people especially modern Christians and youth Herbalists are giving up because of the restriction on application for a permit for collection of medicinal plants and harassment from middlemen Road construction e.g Kolol-Toror Deforestation for farming and construction *K. crenata* is termed as male and believed to be poisonous by some people in western Kenya hence care less about its sustainability	Mainly wild Grow in forests or near homesteads A few people have planted one or two plants on their farms
K. densiflora Rolfe	Cultivation of forested land Use of herbicides especially in tea plantations kills the plants Increase in population increases the demand for more land for agriculture They grow naturally in farms and can be uprooted for farming Overexploitation Young generation lacks knowledge on the value of the plants Affected by prolonged dry season/ rising temperature	Wild
K. glaucescens Britten	Its growth depends on availability of rainfall (Dry up during rainy season)	Wild Pot-plants
K. laciniata (L) DC.	Grows on roadsides and in degraded rocky areas	Wild
K. lanceolata (Forssk.) Pers.	They grow naturally in farms (weeds) and can be uprooted for farming Land degradation-quarrying Growth depends on availability of rainfall (Dry up during rainy season) Reduced due to changing climatic conditions becoming dryer/higher temperatures/prolonged drought	Wild
K. lateritia Engl.	Clearing and fragmentation of forests e.g Chepalungu Grows in rocky degraded areas	Wild

K. marmorata Baker	Overexploitation Collected from the wild distant population for trade in tree nursery Its use not known by young herbalists in some places	Wid
K. nyikae Engl.	Grows at the bed of rocks in degraded landscapes	Wild
K. obtusa Engl.	Burning of vegetation affects the plant Clearing forests for farming Prolonged drought New generation does not know the value of the plants	Wild
K. pinnata (Lam.) Pers.	Grows on roadsides	Wild
K. prittiwitzii Engl.	Land cultivated for agriculture Human population increase puts pressure on existing land Mainly found on rocks/stones Deforestation for farming Forested land leased to locals for cultivation Burning of bushes on hills for cultivation Overexploitation Used during charcoal burning	Wild A few people plant them on their farms

Anthropogenic threats to different *Kalanchoe* species in Kenya (cultivation, infrastructure development, overexploitation) as well as prolonged drought and floods due to climate change result in habitat loss. Informants in this study observed that the loss and fragmentation of natural forests such as Chepalungu has been exacerbated by deforestation and the opening up of forested areas to agriculture. Species like *K. fadeniorum, K. ballyi, K. bipartita* and *K. nyikae*, were conspicuously absent from localities where they had previously been recorded. Elderly residents from the vicinity of the known *Kalanchoe* localities who were asked about the plants' disappearance had no knowledge of it.

The informants who were involved in road construction and farming in several of the *Kalanchoe* localities also mentioned how the habitats had been damaged by the burning and cutting of bushes on hillsides for cultivation and road construction such as the Kolol-

Toror road in the Rift Valley. The primary causes of the reduction in the plant population over the previous ten years (2010-2020) according to elderly informants across the study area were reported as being overexploitation and the aforementioned factors. The plants are said to be common during the sporadic rainy seasons particularly in the eastern and coastal regions. The lack of vegetation was corroborated by a survey conducted in the area during the dry season, when even the more succulent plants (*Euphorbia* spp. and invasive cacti, such as *Opuntia* spp.) wilted. The younger generation's lack of knowledge and interest about these plants' value intensifies the risk to their sustainability. Restrictions on medicinal plant collection and harassment from middlemen further complicate conservation efforts, particularly for species like *K. crenata*, *K. densiflora* and *K. marmorata*.

Generally, a steady decline and disappearance of *Kalanchoe* in Kenya as noted by Dr. Paul Kirika (pers. com.) of the East African Herbarium, elderly informants from places such as Kwale, Kilifi and Makueni and as observed during field studies result from changes in land use activities or their impacts (Table 4.8, Figures 4.8 and 4.9, Plate 4.2 A-F, H-I, Appendix 12). This study revealed that impacts from unpredictable climate variability such as extended droughts and floods and their unforeseen effects have led to significant reductions in the *Kalanchoe* populations. This was particularly evident in Makueni, Machakos, Kitui, Kibwezi, certain areas of Kwale and Kilifi, where very few or no *Kalanchoe* plants were found. There were only patched remnants of native succulent

Euphorbia L. and wilted, drought-resistant invading cactus (*Opuntia* Mill.) in some locations.

Likewise, deforestation from construction, farming and fuel production has led to decreased vegetation cover and the associated wild animals nationwide. There were no herbs or tiny bushes in the vicinity during the field visits in some areas such as Chyulu hills because of periodic fires that had consumed the flora. Additionally, the reduced utilization of some *Kalanchoe* species was attributed to the erosion of traditional knowledge, declining appreciation of herbal medicine among younger generations, and various belief-based taboos. About 30% of the informants specifically reported that youth lacked knowledge of *Kalanchoe* plants, their uses, and their conservation, and expressed a general disinterest in acquiring such knowledge.

Although a few potted plants, most likely ornamental, were seen in some Narok County residences. Eighty percent of the participants applied these plants as medication for humans and poultry, in the treatment of sprains and microbial infections. Surprisingly, it was observed that harvesting involved either uprooting the entire plant or picking at least 4–6 leaves per day to utilize until the situation improved, which occasionally led to overharvesting.

Most of the coastal *Kalanchoe* populations like *K. lateritia* and *K. obtusa* had their distribution in some of the degraded areas in Kwale, Kilifi and Taita Taveta decrease or absent *in toto* due to vegetation clearing for construction and settlement hastening their

disappearance (Plate 4.2 A-F). *Kalanchoe fadeniorum*, has become extinct in the wild, the land that once hosted it is bare at Mackinnon road railway station in Kwale. The drying of seasonal rivers in Makueni and Kwale and absence or drying of the plants confirms the climatic change impact on plant populations (Plate 4.2 D).

Informants indicated a decrease in the populations of the 19 species highlighting a range of threats associated with changes in natural habitats' land use practices. These images highlight the critical anthropogenic and environmental factors that threaten the survival and productivity of *Kalanchoe* and associated species. The threats depicted include farming, habitat fragmentation, quarrying, construction, deforestation, forest fires and effects of prolonged droughts and floods leading to habitat loss and fragmentation.

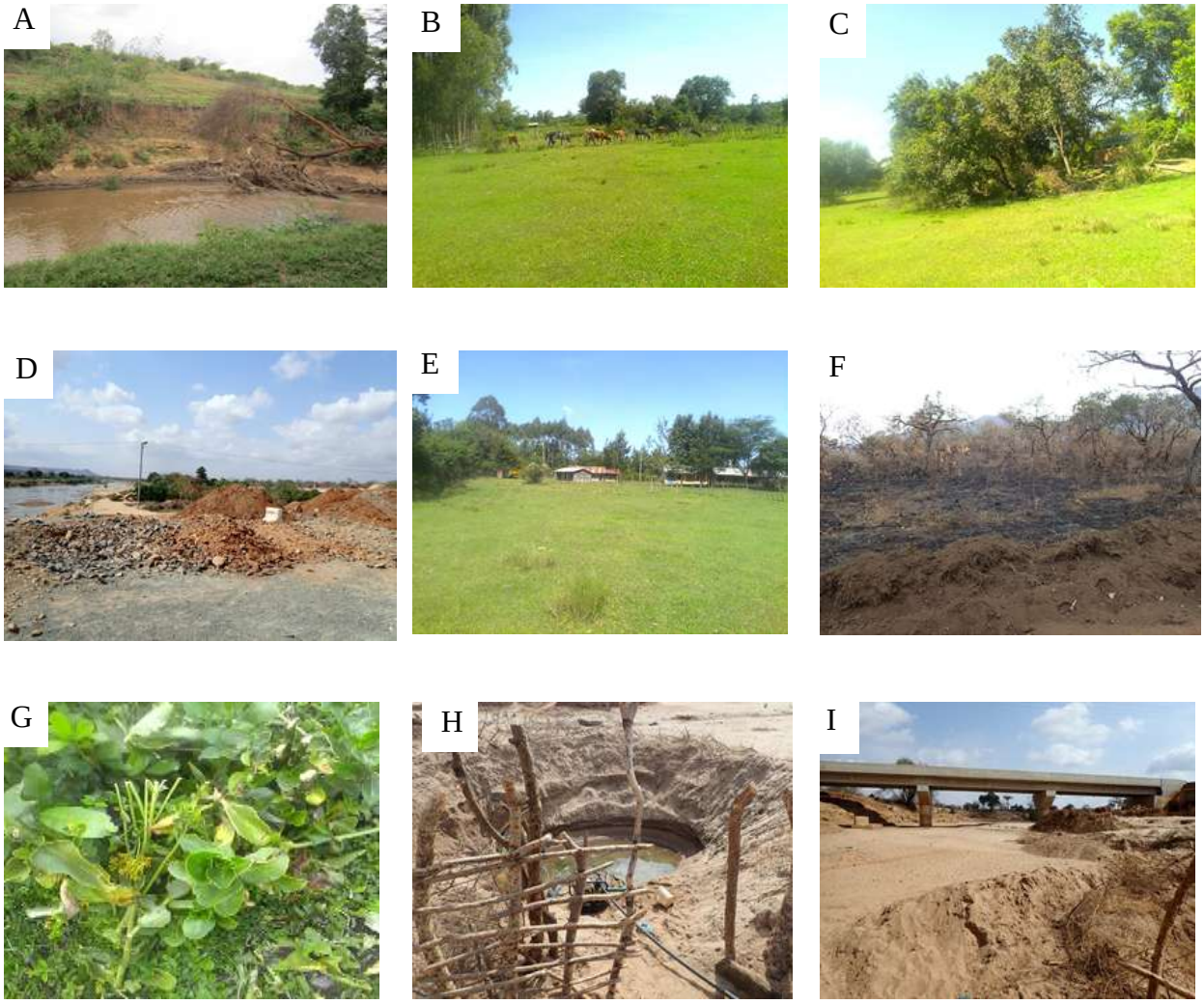

Plate 4.3. Impacts of Human Activities and Climate Variability on Habitats of *Kalanchoe:* A and B Clearing of Vegetation for Farming Crop and Cattle Along River Banks and Use of Chemicals (Narok and Bomet) C, D and E. Habitat Fragmentation Through Quarrying and Vegetation Clearing for Construction in Bomet and Makueni and F and G. Over Harvesting and Cutting of Stems and Inflorescence and Habitat Loss Through Seasonal Forest Fires–Chyulu Hills (Bungoma and Makueni) and H and I. Effect of Prolonged Drought, Dry Lake With a Hole Dug in the Lake Bed Sand for Water (Makueni). Photos by Evusa V.G. in Kenya in 2019/2020.

The proportion of the factors that threaten *Kalanchoe* in Kenya as mentioned by respondents is illustrated in Figure 4.18.

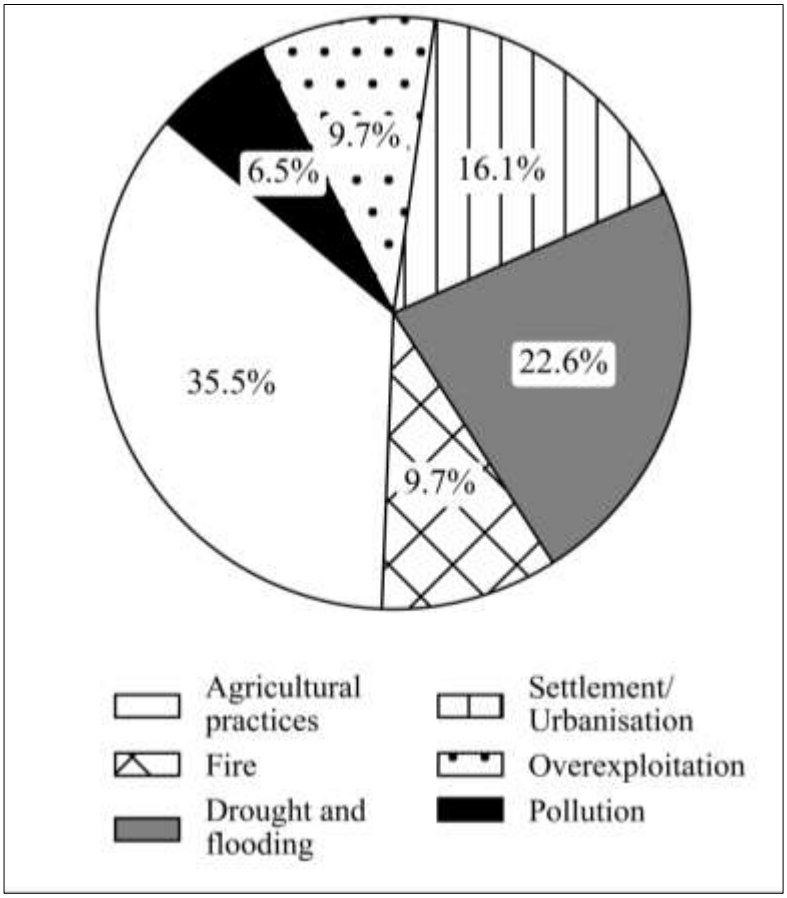

Figure 4.18. Percentage Frequency of the Factors That Threaten *Kalanchoe* Species and Their Habitats. Based on the Number of Times the Particular Factor was Mentioned by the 83 Respondents.

The decline in the *Kalanchoe* population is caused by diverse factors that affect environmental sustainability (Figure 4.18), the largest contributor is agricultural practices (35.5%), followed by drought and flooding (22.6%) and settlement/urbanization (16.1%). Other significant factors include fire and overexploitation in equal proportion (9.7%)**,** and pollution (6.5%) especially due to damping of litter in *Kalanchoe* habitats.

4.4.2 Perceptions on the Trends in *Kalanchoe* Population

Out of the 83 informants, 84% reported reduction in the *Kalanchoe* population and habitat but were not sure of the duration of the decline (Figure 4.19). Figure 4.19 presents survey responses regarding two aspects: the perceived change in plant populations over the last 10 years and awareness among local residents of conservation actions.

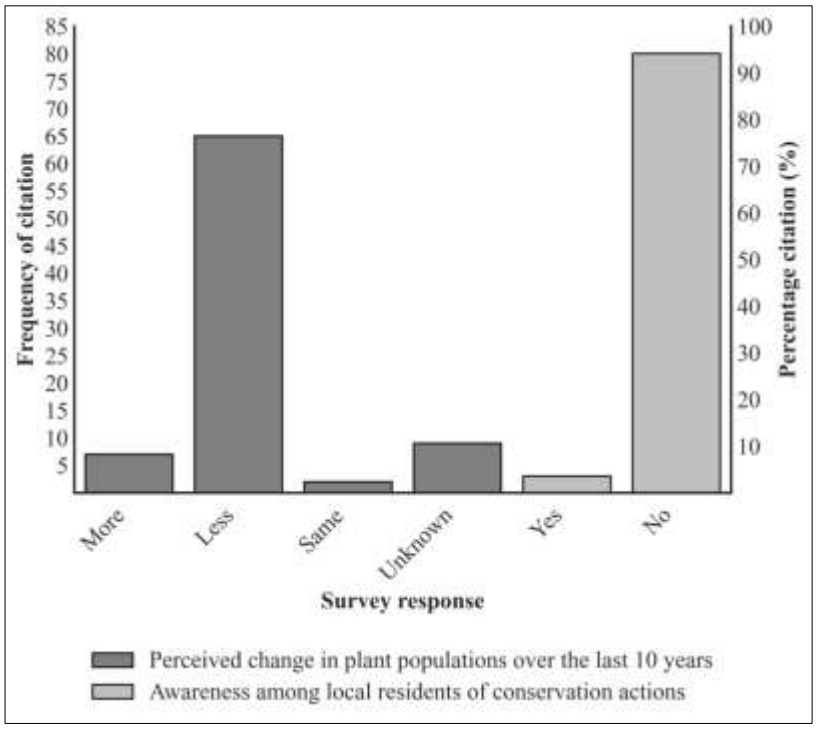

Figure 4.19. Awareness Level of the Declines in Plant Populations and Conservation Actions to Protect *Kalanchoe* Species in Kenya. (Over a Period of 10 Years (2010-2020).

Figure 4.19 uses two vertical axes illustrating the distribution of responses across different categories. For the perceived change in plant populations, the majority of informants around 90% (approximately 27 individuals) indicated that plant populations have

decreased over the last 10 years (2010-2020). A small number of informants (around 2) reported that plant populations have increased, while a few (approximately 3) believed the populations have remained the same. Additionally, a small number (about 3) were completely unaware of the shift in the decline of the species population. Thirty-five percent of the informants reported that the plants are mostly available during the rainy season. Around 90% of the informants expressed unawareness of any conservation efforts implemented to mitigate the population decrease of the *Kalanchoe* plants.

About 10%, of the informants largely from Taita Taveta and Narok, stated that since the community's forests were naturally conserved, conservation was everyone's duty and breaking laws put in place to protect the forests attracted a penalty which included imprisonment. This was made feasible by the development and promotion of alternative revenue streams by the local government and community or by the community's resource conservation culture like farming and trade in non-timber products..

4.4.3 Historical Localities

Close to 104 known localities of *Kalanchoe* were revisited during a one and a half -year field work but the taxa could not be traced in nearly 50 percent of the cases (Figure 4.20). Sixteen out of the localities for 19 species were revisited, but only 50 populations (48%) of the 104 localities for the 16 species were refounded. Apart from *K. lateritia* and *K. nyikae*, endemic species such as *K. fadeniorum, K. ballyi, K. bipartita* were also not seen in any of their documented localities during these field visits.

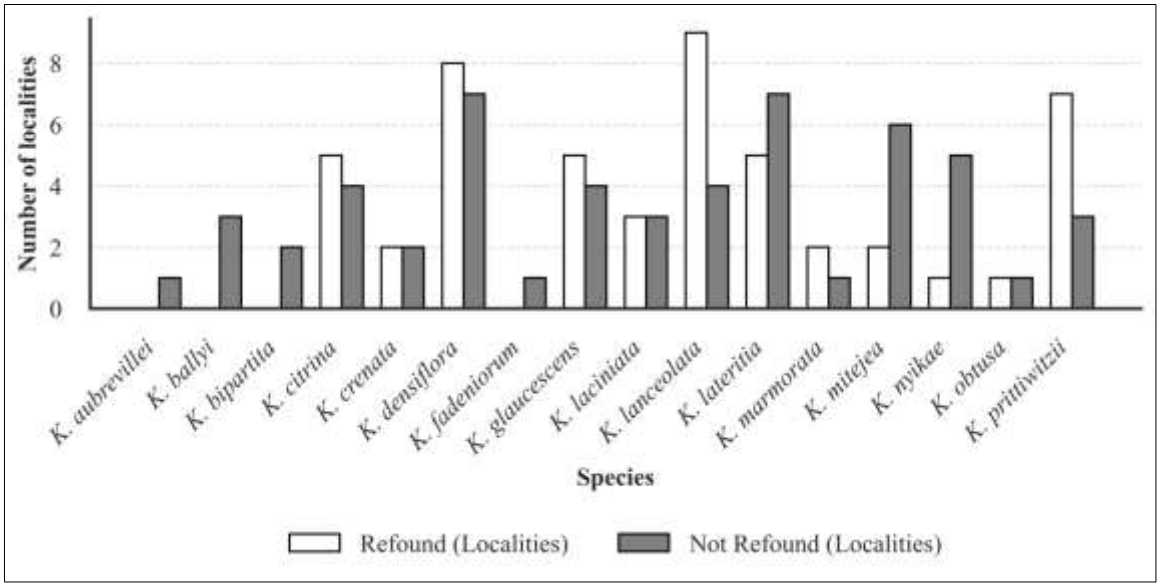

Figure 4.20. Number of Revisited Localities of *Kalanchoe* With Information of Whether or not They Were Refound.

Seven species (*K. crenata*, *K. laciniata*, *K. lateritia*, *K. marmorata*, *K. mitejea*, *K. nyikae*, *K. obtusa*) were located at <50% of the previously known populations but four species (*K. aubrevillei*, *K. ballyi*, *K. bipartita* and *K. fadeniorum*) were not located at all. However, no known localities of three species (*K. boranae*, *K. ndotoensis* and *K. lugardii* Bullock) were visited.

Some of the *Kalanchoe* species, mainly distributed in the Kenyan coastal and Rift Valley regions, could not be traced in the localities where they were previously documented (see Figure 4.21). These include Narok (gorge on the Narok river near Narok town), Bomet (Sotik forest near Sisi river and Chepalungu forests), Kilifi (Arabuko Sosoke forest margin) and Kwale (Tiwi, Mwaluganji). The areas had fragmented vegetation. The

localities where species were refound and not refound during field work are shown in the Kenyan map in Figure 4.21.

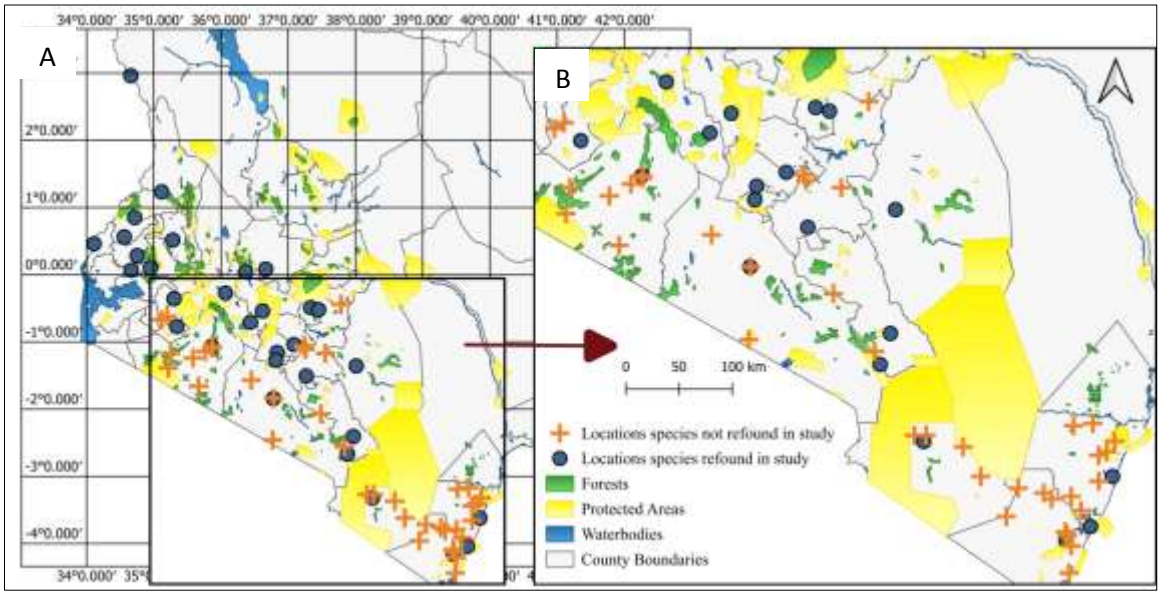

Figure 4.21. A Map of Kenya Showing Localities Visited and Whether *Kalanchoe* Species Were Found or Not.

In Bomet, *K. lateritia* var. *pseudolateritia* is threatened with deforestation, flooding, cultivation and construction since Chepalungu forest is a seasonally flooded bushland mainly due to human activity. The study found that *K. lateritia* var. *pseudolateritia* was rare; with fewer than five mature plants growing about 100 m apart about 1km from the edge of a bushland that was earlier forested. Another known locality of *K. lateritia* var. *pseudolateritia* was a forest near the Sisi River where a school had been constructed and coupled with other human activities the forest which hosted *Kalanchoe* species is now highly fragmented. Only a few populations could be traced, some on fragmented woody bushlands on the school compound including one population comprising less than ten

mature plants and seedlings on the playground with others near buildings. Some of the plants were found to be freshly broken and left on the ground. According to a local who directed us to the school compound, this was the only locality in that vicinity still hosting the seemingly fast disappearing *K. lateritia* var. *pseudolateritia* plants and it is here that most of the collections actually took place. Furthermore, some of the taxa are found within the Mau forest complex which has sadly undergone massive destruction.

In Narok County, several *Kalanchoe* species could not be traced in Syabei Gorge and near Enkare Narok River, its known localities, with land use practices such as construction, damping of litter, quarrying and natural calamities like flooding and consequential breakage of river banks due to flooding in habitats that formerly had the plants seeming to be the main drivers to the populations' reduction. The earliest known collection was made in 1900, according to herbarium data, with the most recent one occurring in 2012 yet less than ten plants (mature ones and seedlings) were seen in all of the locations where the plants were inspected.

4.4.4 Preliminary Reassessment of the Conservation Status of *Kalanchoe* Species in Kenya

Using the GeoCAT tool, analyses were done on 19 species which, based on low AOO, not only revealed the endangered status but also the vulnerable status of the *Kalanchoe* species in Kenya (Table 4.9).

Table 4.9. Preliminary Analyses of the Conservation Status of *Kalanchoe* Species in Kenya (CR- Critically Endangered, EN- Endangered, LC- Least Concern, NT- Near Threatened, VU- Vulnerable, EW- Extinct in the Wild).

Kalanchoe species	Extent of Occurrence (EOO)	Conservation status	Area of Occupancy (AOO)	Conservation status	IUCN (2024) status
K. aubrevillei Raym.-Hamet ex Cufod.	22,977.398 km^2	NT	52.000 km^2	EN	unknown
K. ballyi Rahm-Hamet ex Cofod.	12,763.712 km^2	VU	64.000 km^2	EN	EN
K. bipartita Chiov.	51,996.142 km^2	LC	12.000 km^2	EN	unknown
K. boranae Raadts	0.000km^2	CR	8.000km^2	CR	unknown
K. citrina Schweinf.	725,996.706 km^2	LC	196.000 km^2	EN	unknown
K. crenata (Andrews) Haw.	147,654,788.633 km^2	LC	1,404.000 km^2	VU	unknown
K. densiflora Rolfe	1,404.000 km^2	LC	46,504,860.607 km^2	VU	LC
K. fadeniorum Raads	0.011 km^2	CR	8.000 km^2	CR	EW
K. glaucescens Britten	47,466,243.273 km^2	LC	356.000 km^2	EN	Unknown
K. laciniata (L) DC.	114,984,459.123 km^2	LC	1,540.000 km^2	VU	Unknown
K. lanceolata (Forssk.) Pers.	124,487,503.046 km^2	LC	1,576.000 km^2	VU	Unknown
K. lateritia Engl.	59,845,283.541 km^2	LC	472.000 km^2	EN	LC

K. lugardii Bullock	49,040.283 km^2	LC	12.000 km^2	EN	Unknown
K. marmorata Baker	189,717,869.987 km^2	LC	436.000 km^2	EN	Unknown
K. mitejea Leblanc and Raym.-Ham	233,144.581 km^2	LC	84.000 km^2	EN	Unknown
K. ndotoensis L.E. Newton	0.000 km^2	CR	4.000 km^2	CR	Unknown
K. nyikae sensu stricto Engl.	957,672.727 km^2	LC	132.000 km^2	EN	LC
K. obtusa Engl.	111,732.546 km^2	LC	76.000 km^2	EN	VU
K. prittwitzii Engl.	111,732.546 km^2	LC	76.000 km^2	EN	Unknown

The results of the preliminary analyses of the conservation statuses of the various *Kalanchoe* species, reveal discrepancies between their widespread distribution and localized vulnerabilities. While many species are classified as Least Concern (LC) for EOO, their AOO and specific threats lead to more critical statuses like Endangered (EN) or Critically Endangered (CR). Some species, such as *K. boranae* and *K. ndotoensis*, face extreme risks with minimal or zero EOO and small AOOs. Conservation status revealed that three species are critically endangered (CR), 12 endangered (EN) and four vulnerable (VU). These findings highlight the importance of considering both EOO and AOO in conservation planning to address overlooked species and localized threats effectively.

4.4.5 Reassessments of the Conservation Status of Infraspecific Taxa of *K. lateritia* and *K. nyikae* species.

Information gathered during field observations and as noted by informants in this study, the population of both *K. lateritia* and *K. nyikae* in Kenya have declined mainly due to habitat loss and fragmentation brought about by the below-listed activities leading to their classification as Endangered (Table 4.10). The Revised Red List category and criteria, along with any remarks regarding threats or additional reasons for the assessment, are listed for every taxon. This reassessment employed criterion B which monitors changes in a taxon's distribution range with small populations within a relatively small geographic area combined with noticeable habitat loss and fragmentation supporting the IUCN requirement.

Table 4.10. Reassessment of *K. nyikae* and *K. lateritia*, Species and their Infraspecific Taxa in Accordance With the IUCN Red List Criteria and Categories Version 23.1 (IUCN, 2025).

Scientific name	IUCN Category	Criteria	Comments/threats
K. lateritia	EN	B2ab(iii) (AOO 472.000 km^2)	Agriculture and construction
K. lateritia var. *lateritia*	EN	B2ab(iii) (AOO 228.000 km^2)	Cultivation and construction
K. lateritia var. *prostrata*	EN	B1ab(iii) B2ab(iii) (AOO 36.000 km^2)	Deforestation, construction, quarrying and cultivation
K. lateritia var. *pseudolateritia*	EN	B1ab(iii)+B2ab(iii)(AOO 24.000 km^2)	Deforestation, Agriculture, construction and habitat fragmentation
K. nyikae sensu stricto	EN	B2ab(iii) (AOO 132 000km^2)	Quarrying and habitat loss and fragmentation
K. nyikae subsp. *nyikae* (*K. nyikae*)	EN	B1ab(iii) B2ab(iii) (AOO 52.000km^2)	Quarrying and habitat loss and fragmentation
K. nyikae subsp. *auriculata* (*K.*x *auriculata*)	EN	B1ab(iii) B2ab(iii) (AOO 60.000km^2)	Quarrying, breaking of river banks, flooding, habitat loss and fragmentation

From Table 4.10 both *K. lateritia* and *K. nyikae* and their intraspecific taxa are categorized as Endangered (EN) under the IUCN Red List, primarily due to their restricted areas of occupancy (AOO) and ongoing habitat degradation. The primary threats include habitat loss and fragmentation caused by deforestation, agricultural expansion, construction activities, and quarrying. Among the varieties, *K. lateritia* var. *pseudolateritia* and *K.*

nyikae subsp. *auriculata* face the most severe threats due to their highly restricted AOO and multiple overlapping risks, including habitat fragmentation, quarrying, and environmental disturbances like flooding (See Appendix 15 for publications from this research).

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CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This chapter discusses the results analysed in chapter four under the following subtopics: taxonomy, phylogeny, ethnobotany, conservation, conclusion, recommendations and further studies.

5.0 Demographic Patterns of Informants

Knowledge of *Kalanchoe* use exhibited clear gender patterns, with men demonstrating greater familiarity than women in the sampled localities. As indicated in Figure 4.1, 80% of men reported higher knowledge of *Kalanchoe* plants than women—a finding consistent with an observation made in Western Kenya by Chebii *et al*. (2020) . This gender disparity reflects socio-cultural dynamics in ethnobotanical knowledge transmission, where men's greater mobility and involvement in outdoor tasks like harvesting, clearing vegetation and herding cattle provides more exposure to *Kalanchoe* plants especially in the pastoralist communities. This trend was also noted by Oruganti *et al*. (2023) supporting the view that traditional healing roles are often dominated by men (Mayaba, 2019), although each community has its own knowledge keepers who could be of either gender.

Age related trends further illuminate the social structure of knowledge distribution. Middle-aged males (21-60 group) formed the largest group of informants, reflecting their active engagement with rural environments and daily interaction with plants during their working lives which was confirmed by their availability in *Kalanchoe* habitats especially in the pastoral communities.

Women of over the age of 60, who constituted the majority of respondents in this age group, demonstrated greater openness in sharing information than men of the same age category across Kenya; this pattern is accordant with findings reported by Cazalis *et al*. (2024). However, the relatively low representation of elderly informants may be influenced by cultural norms in some communities such as among the Maasai where elders are often shielded from frequent inquiry..

The limited participation of the younger individuals (18-20 years) shows concern about the uncertainty in intergenerational knowledge transmission in most Kenyan communities. As as reported in this study, young people are not interested in traditional medicine or other rituals and practices they consider to be outmoded and thus may not value indigenous knowledge, a fact has also been highlighted by Tugume *et al*. (2016) and Balick and Cox (2020). Furthermore, as opined by Kokwaro (2009) and later by van't Klooster *et al*. (2016) deeper knowledge of medicinal plant use is a highly kept secret that is only shared with mature individuals who can be trusted. This highlights the uncertain future of traditional medicine prompting urgent action to enhance its survival. This secrecy, combined with youth disinterest, signals an uncertain future for traditional medicine and highlights the urgent need for intentional knowledge preservation and transmission initiatives.

Luckily, among communities such as the Maasai as indicated by Nankaya *et al.* (2020), traditional medicine is still active and knowledge is shared between generations; bolstering the findings in this study that the Maasai have more ethnobotanical knowledge about

Kalanchoe compared to any other ethnic group. In most of the pastoralist communities visited—like Pokot and Duruma, young men who are not necessarily traditional healers are involved in the collection of the plants, otherwise in most cases herbalists do the gathering themselves.

The higher representation of farmers in the study indicates their prominent involvement or significant presence, near the localities of *Kalanchoe* that were sampled especially in the pastoralist communities where the main activity is livestock herding. Besides most people who don't have white collar jobs always designate their profession as farming even when they do not practice it because some feel ashamed to disclose their employment status especially if they are jobless or do lowly valued jobs. In contrast, the lower representation of the other groups suggests that they show limited engagement or were not found in places where *Kalanchoe* grows naturally in the wild during the time of field visit. *Kalanchoe* grows in disturbed open places or forest margins and by roadsides where farmers interact more with the plants than sedentary workers. The moderate representation of businessmen and herbalists suggests their partial involvement in traditional medicine or related activities and partly due to the spiritual attachment of herbalists to herbal medicine. This variation in representation across occupations might reflect the differing knowledge levels on the utilisation of *Kalanchoe* species in Kenya. Conversely, the results revealed a balanced distribution of education levels across the informants, indicating that literacy level does not affect the perspective of informants on uses of *Kalanchoe* although, the non-

formal education (majorly farmers) category had a slightly higher proportion of participants.

The distribution of knowledge on *Kalanchoe* species across ethnic groups underscores the influence of cultural practices, ecological interactions, and traditional uses on biodiversity awareness. The pronounced familiarity of the Luhya and Maasai with specific species, such as *K. crenata* and *K. marmorata* respectively, may reflect the cultural significance of these species for medicinal and other traditional purposes mainly affected by their geographical distribution. Conversely, the limited knowledge among groups like Luo and Kisii might result from geographical distribution and availability of the plants, reduced cultural emphasis on these species and the limited sample size.

Luckily, it was reported that Luos use *K. densiflora* to treat protozoan and viral infections including malaria that is prevalent in the region, rheumatism and arthritis (Sikolia, 2018; Wainaina *et al*., 2019). The patterns also suggest that certain species, such as *K. prittwitzii*, may have broader cultural or ecological significance, given their recognition across multiple groups. *Kalanchoe* are valuable resources across communities in Kenya.

5.1 Morphological and Molecular Delineation of the *K. lateritia* and *K. nyikae* Species Complexes

This section discusses the role of morphological and DNA markers in clarifying the systematics of *K. lateritia* and *K. nyikae*.

5.1.1 Morphological Delineation of the *K. lateritia* and *K. nyikae* Species Complexes

The PCA results reveal clear patterns of morphological differentiation among the three varieties of *K. lateritia*, with the first principal component (PC1) explaining the vast majority of variation (88.75%). The dominant influence of inflorescence length (IL) on PC1 highlights the importance of floral traits in varietal distinction. This finding aligns with field observations that inflorescence characteristics are among the most visually and taxonomically distinct features within the genus.

Kalanchoe lateritia var. *lateritia*'s tight clustering around the origin indicates a high degree of internal consistency, particularly in traits such as inflorescence structure, upright growth habit, and leaf dimensions. This homogeneity suggests a relatively stable gene pool, potentially shaped by a narrower ecological range or consistent selective pressures within its native habitat.

In contrast, *K. lateritia* var. *pseudolateritia* exhibited a much wider morphological spread, especially along PC1 and PC3. This dispersion indicates greater phenotypic plasticity, which may stem from adaptation to diverse environmental conditions such as rocky outcrops or variable woodland margins. Traits contributing to this variability include differences in leaf width, leaf base length, and inflorescence morphology, which were captured by both PC1 and PC3 loadings. The presence of outliers in the PCA plot suggests that this variety might include transitional forms or individuals influenced by microhabitat-specific factors—or even reflect underlying genetic divergence not captured in the current morphological dataset.

Kalanchoe lateritia var. *prostrata*, while appearing morphologically similar to *K. lateritia* var. *lateritia*, displayed a prostrate growth habit and was mostly sampled from coastal or lowland habitats. Although PCA placed it within the *K. lateritia* var. *lateritia*, cluster, this may be due to the limited trait dataset or small sample size. Its apparent morphological alignment with *K. lateritia* var. *lateritia*, warrants further investigation using a more comprehensive trait matrix, including phenological, anatomical, or molecular characters. This could help determine whether the observed overlap reflects true taxonomic affinity or an underestimation of its morphological distinctiveness.

From a taxonomic standpoint, the results strongly support the continued recognition of *K. lateritia* var. *pseudolateritia*, as a distinct variety due to its greater morphological variability and ecological breadth. The relationship between *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata*, however, remains less clearly defined from the morphometric analysis as was also observed in the cluster analysis results. The dendrogram for *K. lateritia* varieties demonstrates substantial genetic variability within *K. lateritia* and supports the taxonomic complexity of the species. The dispersion of *K. lateritia* var. *lateritia* across multiple clusters implies that this variety exhibits a wide range of genetic or morphological traits, which may be attributed to environmental adaptability, hybridization, or evolutionary divergence.

The clustering of *K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* accessions into their own distinct groups highlights their potential as genetically or morphologically distinct varieties within *K. lateritia*. Additionally, the observed overlaps among different

varietal clusters may suggest historical hybridization or introgression events, which could have contributed to the rich phenotypic plasticity seen within *K. lateritia* var. *lateritia*. This genetic interconnectedness also emphasizes the importance of preserving a wide representation of these accessions for conservation and breeding programs. These findings may not conclusively support formal recognition of the varieties. However, the dendrogram served as a foundational tool in understanding the genetic structure and diversity of *K. lateritia*.

The PCA results provide compelling evidence for morphological differentiation between *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae*. The clear separation, particularly along PC1, supports the classification of these two subspecies as morphologically distinct entities. The dominant role of inflorescence length in PC1 indicates its importance as a key distinguishing character. This trait's high loading suggests that differences in reproductive structures may be a strong driver of subspecific divergence in this taxon.

The wider dispersion of *K. nyikae* subsp. *auriculata* individuals along PC1 may reflect greater environmental plasticity or underlying genetic diversity. This pattern could be the result of adaptation to a broader range of ecological niches, such as variations in altitude, soil type, or microclimate. On the other hand, the tighter clustering of *K. nyikae* var. *nyikae* suggests more uniform morphological traits, which may correspond with a more specialized habitat or reduced gene flow.

The significant influence of leaf traits in PC2 and PC3 underscores the relevance of vegetative morphology in understanding intraspecific variation. Although these components account for less variance than PC1, they contribute valuable insights into the complexity of character expression within and between the subspecies.

From a taxonomic perspective, these findings reinforce the current subspecific classification and highlight the value of multivariate analyses in resolving fine-scale morphological differences. Furthermore, the observed variability within *K. nyikae* subsp. *auriculata* suggests the possibility of unrecognized diversity or ecotypes within this group, which may warrant further ecological or genetic investigation. In terms of conservation implications, the broader morphological range seen in *K. nyikae* subsp. *auriculata* may indicate locally adapted populations that deserve targeted protection. Understanding such variation is crucial for effective *in-situ* conservation and for guiding any potential *ex-situ* propagation or restoration programs.

The results of the cluster analysis suggest that the morphological distinction between *Kalanchoe nyikae* subsp. *nyikae* and *K. nyikae* subsp. *auriculata* is not absolute. While general trends in character differences are observed—for example, auriculate versus rounded leaf bases, and subtle differences in growth form—these traits do not consistently segregate the two taxa into distinct morphological clusters.

The intermixing of specimens in the dendrogram implies the presence of morphological overlap**,** which may result from shared ancestry, phenotypic plasticity, or incomplete

divergence. It is also possible that the morphological characters used in the analysis, though useful for field identification, are influenced by environmental factors or developmental stages, leading to variability within taxa.

The presence of *K. nyikae* var. *nyikae* specimens clustering among *K. nyikae* var. *auriculata* groups, and vice versa, raises the possibility of either continuous variation along an ecological gradient or the existence of intermediate forms**,** potentially resulting from introgression or gene flow. These observations call into question the sufficiency of morphological traits alone in resolving subspecific boundaries within this group.

Given the ambiguous clustering pattern, it is recommended that morphological analyses be complemented with molecular, ecological, and geographic data to better understand the evolutionary relationships and taxonomic validity of the subspecies. While *K. nyikae* subsp. *auriculata* may still be recognized based on a constellation of morphological features, its taxonomic status is well determined.

5.1.2 Molecular Relationships Among the *K. lateritia* and *K. nyikae* Species

According to the findings of this study, there is a strong relationship between *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* as they occur within the same clade. They do not separate out as different entities to form separate monophyletic groups and also the overlap in their distribution do not guarantee their recognition at species level or as separate entities. They were previously separated at subspecies level based on the leaf character and chromosome number; *K. nyikae* subsp. *auriculata* has auriculate leaves with

chromosome number of 2n = 68 while *K. nyikae* subsp. *nyikae* has peltate leaves and chromosome number 2n = 34 (Raadts, 1977, 1989; Wickens, 1987).. The two sister groups are closely related to several other species within the same clade but differ markedly in both ploidy levels and biogeography. These related species occupy distinct ecological zones across East Africa: *K. peteri* (2n = 68) is primarily restricted to the arid and semi-arid lowlands of northern Kenya; *K. marmorata* (2n = 34, 2n = 68) has a wider distribution spanning rocky escarpments and dry woodlands in Kenya, Ethiopia, and Somalia; *K. mitejea* (2n = 34) is localized to the dry bushlands of coastal Kenya and northern Tanzania; and *K. germanae* (2n = 34) is confined mainly to upland rocky habitats in central and eastern Kenya. These biogeographical differences highlight the ecological divergence and localized adaptation within the clade.

The taxa also form a subclade to another subclade containing two of the diploid *K. lateritia* species complex varieties *K. lateritia* subsp. *lateritia* and *K. lateritia* subsp. *prostrata* (2n = 34) together with *K. glaucescens* (2n = 102), *K. prittwitzii* (2n = 155-165), *K.* sp. A and B (FTEA) and *K. citrina* 2n = 68. The subclade containing the two subspecies and two varieties is a sister to a weakly supported subclade containing the third variety of *K. lateritia* i.e *K. lateritia* var. *pseudolateritia* together with *K. crenata*, *K. glaucescens*, *K. densiflora* var. *densiflora*, *K. bipartita*, Ethiopian taxa- *K. petitiana, K. quartiniana* and one taxon from Swaziland- *K. alticola*, all vary in ploidy levels in addition to distribution thus making it difficult to clearly define the taxonomic relationships within the species complexes. *Kalanchoe lateritia* var. *pseudolateritia* could have made as a separate entity

but there is an overlap in its distribution. The relationship within *K. crenata, K. glaucescens* complexes and their relationship with other taxa remains unclear in the *FTEA* (Wickens, 1987) and the findings of this study.

Some of the relationships reflected in the phylogenetic tree were postulated by Raadts (1977) and Wickens (1987) through floral characters where *K. marmorata, K. aubrevillei*, *K. mitejea*, *K. nyikae*, *K. boranae* and *K. prittwitzii* have corolla-tube 15-120 mm. long while *K. glaucescens, K. densiflora* and *K. crenata* have corolla-tube 4.5- 12mm. long. The length of the corolla tube overlaps in *K. mitejea*, *K. nyikae* and *K. boranae* (17-22 mm. long) and in *K. glaucescens, K. densiflora* and *K. crenata* (7-12 mm. long). It could be that the Angiosperm 353 probe kit used was not sensitive to the corolla tube length, pubescence and stem characters that distinguish the species in the complexes under study. *Kalanchoe* sp. A and *K.* sp. B are close allies to *K. citrina* in both the *FTEA* but not the phylogenetic tree where they occur more closely to *K. lateritia* and *K. glaucescens* respectively.

Presumed relationships among the *Kalanchoe* taxa based on morphology may not be good enough to delimit taxa within *Kalanchoe* as they vary even within a species and at subspecies levels e.g. indumentum on the stem, leaves and inflorescence vary and are affected by age and geographical distribution of taxa (Raadts 1977). Incorporation of genetic approaches with varied marker systems into the taxonomy of *Kalanchoe* could help clarify the presumed relationships that are largely based on morphology. This was observed in *K. lateritia* var. *lateritia*, which separated from the rest of the *K. lateritia* taxa and aligned with taxa from the country of origin (Mozambique). The specimen looked

slightly bigger than the rest of the *K. lateritia* specimens and it even separates itself from the East African *K. lateritia* taxa.

From the results, most of the variable species complexes within *Kalanchoe* are polyphyletic. The complexity surrounding the *K. lateritia, K. nyikae, K. glaucescens, K. crenata* and *K. lanceolata* among others which have been treated with several varieties, subspecies and forms could possibly result from misclassification or recent gene flow events (Yost *et al*., 2013). The relationship between *K. nyikae* species complexes requires further investigation as the taxa continue to receive more attention (Smith and Figueiredo, 2021). The phylogenetic results of this study seem to contradict their argument as regards the taxonomy of the subspecies although their approach was mainly cytological. The species seem to be monophyletic within a minor subclade but it is in close association with other morphologically related species in the same clade making it to be polyphyletic. Due to the close relationship of the subspecies within the same sub-clade and unresolved monophyly, the status of the two subspecies as in *FTEA* is retained pending further research.

Within the *K. lateritia* species complex, *K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* would have been treated as separate entities but they are not monophyletic and also overlap in distribution. The third variety *K. lateritia* var. *lateritia* is very variable and polyphyletic as depicted by the phylogenetic tree but its relationship with the other varieties is undetermined. The relationship of *K. lateritia* complex with other morphologically related taxa like *K. crenata* and *K. densiflora* (Wickens, 1987) and as also

reflected in the phylogenetic tree remains unclear. It is possible that the Angiosperm 353 probe kit may not be providing variation that is sufficient to delimit or resolve the current infraspecific relationships. Lack of variations of the nucleus could indicate the gene flow followed by concerted evolution at nuclear loci or very short divergence times between taxa (Yost *et al*., 2013). More markers coupled with further morphometric analysis of the entities could shed more light into their infra and interspecific relationships (Tian *et al*., 2021).

There was general agreement of the close relationship of the molecular results and morphological classification (Wickens, 1987) between *K. nyikae* and its sister taxa viz., *K. mitejea*, *K. marmorata*, *K. germanae* and *K. peteri* and not in *K. aubrevillei* and *K. boranae*. *Kalanchoe lateritia* var. *pseudolateritia* overlaps in distribution with other varieties in *K. lateritia* and *K. crenata* hence gene flow could be occurring but with further research its taxonomy and that of *K. lateritia* var. *prostrata* might change.

As Wickens (1987) hypothesized, *Kalanchoe* is a very difficult genus where the distinction between taxa is unclear and due to polyploidy a more simplified system recognizing aggregate species would be more appropriate but results from this study are inconclusive on the placement of some of the *Kalanchoe* species in the phylogenetic tree. Polyploidy as a mechanism of formation in reproductively isolated species and the high rate of hybridization contributed to the diversification and complexity of the genus as portrayed by phylogenetic trees and noted in other studies (Soltis and Soltis., 2009; Horandl, 2022).

Relationships among the *K. lateritia* var. *lateritia, K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia* and *K. nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* will remain unclear until more neutral markers and other more informative methods are used with perhaps more samples for phylogenetic analysis.

A detailed evaluation of the phylogenetic relationships among and within individual species of the genus *Kalanchoe* requires the use of more markers than those applied so far on this group of succulent plants by several authors (Ham and ‘t Hart, 1998, Mort *et al*., 2001; Rodewald *et al*., 2025). The two unidentified species *K.* sp. A and *K.* sp. B do not separate out independently from the rest of *Kalanchoe* taxa but are found embedded in clades containing *K. lateritia, K. glaucescens* and *K. nyikae*. It is possible that these taxa could be their close relatives or could be a variety or subspecies of the aforementioned species but more markers and samples can be used to resolve the ambiguity in their relationships.

The spotted leaves and large inflorescence observed in taxa on the most recent branches of the *Kalanchoe* phylogeny could be an adaptation to suit changing environmental conditions and adaptation to the ever varying habitats. Some taxa like *K. marmorata* are not only among the most beautiful ornamental plants within the floristic boundaries of East Africa but also among the most appreciated as well as traded in the first world countries. *Kalanchoe* species have gained market share in the horticultural industry worldwide (Tian *et al*., 2021). Plant breeders have capitalized mostly on their ability to hybridize and

vegetatively propagate to come up with more attractive and fast growing plants for ornamental, medicinal and other purposes.

5.1.3 Comparison of Morphological and Molecular Findings

Overall, the molecular phylogenetic results and morphological dendrograms show strong agreement. The main differences arise in morphological overlaps, where certain varieties (e.g., *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata*) appear more similar in cluster analysis and genetically indistinct in phylogenetic trees. The separation of *K. lateritia* var. *pseudolateritia* is clearer in molecular data, indicating genetic divergence despite some morphological similarity. The phylogenetic trees reinforce taxonomic classifications, while dendrograms highlight trait-based variations, which may be influenced by ecological adaptations.

The molecular phylogenetic analysis confirms that *K. lateritia* and *K. nyikae* are distinct evolutionary lineages, with well-supported monophyletic clades. Within *K. lateritia*, the varieties (*K. lateritia* var. *lateritia*, *K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia*) exhibit genetic differentiation, with *K. lateritia* var. *pseudolateritia* showing higher divergence, suggesting it may represent a more distinct taxonomic entity. *Kalanchoe nyikae* is divided into *K.* subsp. *nyikae* and *Kalanchoe* subsp. *auriculata*, both closely related but genetically distinct, supporting their recognition as valid subspecies.

The morphometric analyses confirm that *K. lateritia* var. *prostrata* and *K. lateritia* var. *lateritia* frequently group together, indicating strong morphological similarity. *Kalanchoe*

lateritia var. *pseudolateritia* sometimes clusters separately, aligning with molecular data that suggests greater genetic divergence. *Kalanchoe nyikae* subsp. *auriculata* and *K. nyikae* subsp. *nyikae* form distinct clusters but remain closely related, similar to their molecular placement. Some dendrograms suggest greater overlap among varieties due to shared traits, likely influenced by environmental adaptation rather than genetic lineage. *Kalanchoe lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* often show weak separation in morphological clustering, reflecting trait-based similarities rather than deep genetic divergence.

While morphological dendrograms align broadly with molecular results, they show more overlap among varieties due to phenotypic plasticity and environmental influences. The clustering of *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* in dendrograms suggests morphological similarity, partly supported by phylogenetics which reveals underlying genetic divergence. The separation of *K. nyikae* subsp. *auriculata* and *K.* subsp. *nyikae* is evident in both datasets, confirming their distinct status. The genetic distinctiveness of *K. lateritia* var. *pseudolateritia* and *K. nyikae* subsp. *auriculata* suggests they may be evolving adaptations to specific ecological niches, warranting conservation attention. Morphological variations, especially in *K. lateritia*, might be driven by environmental pressures rather than deep evolutionary separation, highlighting the importance of ecological studies.

5.2. Phylogenetic Relationships and Evolutionary Trajectories in the Genus *Kalanchoe* in Kenya

The evolutionary relationship among *Kalanchoe* species is explained in this section based on the ASTRAL and ML trees obtained in this study.

5.2.1 Madagascar as the Center of Origin

The phylogenetic results from this study corroborate previous findings (Gehrig *et al*., 2001; Smith and Figueiredo, 2018) suggesting Madagascar as the center of origin and adaptive radiation for *Kalanchoe*. Malagasy taxa, particularly *K. linearifolia*, resolved as the most basal lineage in both ASTRAL and ML trees (Figures 4.20 and 4.21), supporting this hypothesis. This species forms a distinct basal node, possibly indicating a historical bottleneck event.

Gehrig *et al*. (2001) also observed a correlation between genotypic variation and Crassulacean Acid Metabolism (CAM), noting that humid-adapted Malagasy *Kalanchoe* species showed reduced CAM activity. This pattern may also be relevant to Kenyan *Kalanchoe* species, as variations in habitat—from humid coastal and montane regions to arid inland zones—could similarly influence the degree of CAM expression and physiological adaptation to water stress. This supports a scenario where the genus originated in humid environments and later adapted to arid habitats as it dispersed.

5.2.2 Dispersal Patterns and Biogeography

The evolutionary trajectory suggested by this study indicates a dispersal route from Madagascar to Arabia and Asia, followed by southern Africa, central and western Africa, and finally East Africa. This biogeographic pattern is reflected in the progressive derivation of East African taxa, such as *K. nyikae*, *K. peteri*, *K. germanae*, and *K. mitejea*, which appear as the most derived in the phylogenetic tree.

Interestingly, taxa from Mozambique showed closer affinity to Malagasy species than to those from South Africa, indicating an early dispersal route through Mozambique. The Indian Ocean may have acted as a barrier, contributing to genetic differentiation between populations (Raadts, 1977).

5.2.3 Subgeneric Classification and Phylogenetic Structure

Historically, there has been considerable debate on the infrageneric classification of *Kalanchoe*. Different authors have variously recognized one to three separate genera or subgenera (Hamet, 1907; Berger, 1930; Descoings and Lavranos, 2006; Smith and Figueiredo, 2018). In this study, the traditionally recognized subgenera (*Kalanchoe*, *Bryophyllum*, and *Kitchingia*) were used, consistent with the treatment by Gehrig *et al*. (2001).

Additional subgenera, including *Fernandesiae* Gideon F.Sm. (Southern Africa), *Calophygia* Des. Emend. Gideon F.Sm. (Smith *et al*., 2021) and Alatae (Gideon F.Sm.) Raym.-Hamet ex Gideon F.Sm.), have been introduced in recent taxonomic updates.

Rodewald *et al*. (2025) included species from four out of five recognized subgenera, highlighting the need for more comprehensive inclusion, especially of under-sampled taxa. In their study, *K.* subgenus *Calophygia* resolved as a sister to the rest of the genus, indicating the necessity for further refinement of infrageneric relationships.

5.2.4 Notable Phylogenetic Findings and Species-Level Patterns

The phylogenetic tree recovered two major clades. The first, predominantly Malagasy clade, includes *K. campanulata* (subgenus *Kitchingia*) as a sister to members of subgenus *Bryophyllum*, reflecting shared evolutionary history. The second clade, largely African, includes the East African endemics, which are among the most recently derived taxa.

The inclusion of *K. lateritia* from Mozambique showed divergence from other African populations of the same species, potentially due to the barrier effect of the Indian Ocean or environmental adaptation. This supports earlier assertions that *K. fernandesii* Raym.-Hamet from Mozambique may be conspecific with *K. lateritia* var. *lateritia* due to shared morphological traits and necessitates further investigation of the outlier taxon to ascertain its relationship with its sister taxa and possibly *K. fernandesii*.

5.2.5 Biogeographic and Evolutionary Implications for East African Taxa

The East African species (*K. nyikae*, *K. germanae*, *K. mitejea*, *K. peteri*) represent the terminal end of the phylogenetic radiation. These taxa exhibit distinctive morphological features such as mottled leaves, a trait that appears more derived than the plainer green-leaved ancestors.

The outlier placement of *K. nyikae* subsp. *nyikae* in the phylogenetic structure poses questions about possible hybridization, cryptic diversity, or incomplete lineage sorting. While Smith (2023) suggested an exotic origin, this study's data supports its nativity to East Africa (POWO, 2025), pending further verification through broader sampling and additional molecular markers.

5.2.6 Monophyly and Rapid Radiation

The use of *Cotyledon barbeyi* Schweinf ex Baker as an outgroup confirmed the monophyly of *Kalanchoe*, consistent with its derivation from Cotyledon-like ancestors as opined by other authors (Berger, 1930; Mort *et al*., 2001). High bootstrap support at the tips and shorter branches in the major clades suggest a rapid radiation event among African taxa, a trend that is supported by other auhors (Czech *et al*., 2017; Bernardini *et al*., 2024).

This rapid diversification likely resulted in closely spaced speciation events, contributing to the taxonomic complexities observed today. The genetic clustering and geographic signals underscore the importance of integrating both molecular and morphological data to resolve phylogenetic uncertainties.

5.2.7 Insights Into the Phylogenetic Relationships Among the *Kalanchoe* Species in Kenya

This study provides the first comprehensive phylogenetic analysis of Kenyan *Kalanchoe* species using the Angiosperm 353 universal probe set. By analyzing taxa such as *K. aubrevillei*, *K. ballyi*, *K. bipartita*, *K. boranae*, *K. citrina*, *K. crenata*, *K. densiflora*, *K. fadeniorum*, *K. glaucescens*, *K. laciniata*, *K. lanceolata*, *K. lateritia*, *K. marmorata*, *K.*

mitejea, *K. ndotoensis*, *K. nyikae*, *K. obtusa*, *K. pinnata*, and *K. prittwitzii*, this work revealed evolutionary patterns and taxonomic relationships that shed light on ecological adaptation and conservation priorities.

5.2.8 Phylogenetic Clades and Evolutionary Groupings

The phylogenetic trees constructed in this study show substantial congruence with the morphological classifications previously outlined in the *Flora of Tropical East Africa* (Wickens, 1987), though they also uncover new insights. A notable finding is the formation of distinct subclades within the major *Kalanchoe* clade, suggesting divergence from a common ancestor and subsequent independent evolution.

Species such as *K. lateritia*, *K. nyikae*, and *K. lanceolata* form a closely related subclade, supporting their classification as distinct yet evolutionarily proximate taxa. Their grouping may reflect shared ecological niches and common adaptive traits, such as CAM photosynthesis for drought tolerance. Similarly, the close genetic clustering of *K. crenata* and *K. densiflora* aligns with their morphological similarity and shared habitat preferences.

In contrast, *K. fadeniorum* and *K. prittwitzii* exhibit substantial genetic differentiation, likely due to geographic and ecological isolation. These findings highlight the role of habitat-specific adaptations and selective pressures in driving speciation within the genus.

5.2.9 Biogeographical Origins and Diversification Patterns

Some Kenyan species appear to have originated outside the country and diversified locally. For example, *K. pinnata*, though sampled in Kenya, clusters closely with Malagasy taxa—

consistent with its origin in Madagascar. Likewise, *K. lanceolata* likely followed a dispersal route from Madagascar through Arabia and Asia into Africa, arriving via South Africa. The phylogenetic position of *K. glaucescens* suggests a diversification path through Mozambique and South Africa to Eastern and Central Africa.

The diversification order within Kenyan taxa is proposed as follows: after the diversification of *K. glaucescens* and *K. crenata,* followed by *K. prittwitzii*, *K. sp. B (FTEA), K. ballyi*, *K. lateritia* var. *prostrata,* and *K. citrina*, other species such as *K. mitejea*, *K. marmorata*, *K. germanae*, and subspecies of *K. nyikae* followed suit. The morphological traits such as the erect stem in *K. lateritia* and auriculate leaves in *K. nyikae* are likely ancestral.

The relationships among Kenyan taxa—e.g., *K. boranae*, *K. prittwitzii*, *K. glaucescens*, and *K. lateritia* var. *lateritia*—reflect concurrent diversification events, likely shaped by environmental heterogeneity and geographic barriers.

5.2.10 Taxonomic Implications

The results validate the classification of certain morphologically similar taxa as genetically distinct species. For instance, although *K. ballyi* was previously considered a subspecies of *K. usambarensis* (Raadts, 1977), this study shows they belong to different clades, supporting their distinction. Additionally, the separation of *K. glaucescens* and *K. obtusa* from the main clusters suggests they may represent early-diverging lineages and could warrant reevaluation of their taxonomic status.

The placement of unnamed taxa, such as *K. sp. A (FTEA)* and *K. sp. B (FTEA)*, suggests close affinity with recognized species like *K. lateritia*, *K. citrina*, and *K. ballyi*, implying that they may represent natural variants or subspecies. For example, *K.* sp. *B (FTEA)* aligns with *K. lateritia* var. *prostrata*, suggesting a close relationship due to overlapping distributions.

5.2.11 ASTRAL and ML Phylogenetic Trees Comparison

Both ASTRAL and ML (Figures 4.20 and 4.21) trees differed in most of the African taxa clades and were better supported at the tips and in minor clades than along the nodes and branches of main clades. It was also noted that the major clades had shorter branches than the taxa within the minor subclades. In both ASTRAL and ML Trees, there was coincidence in the placement of *K. linearifolia* and the rest of the Malagasy taxa as the most basal group. *Kalanchoe campanulata* was sister to the rest of the *K.* subgenus *Bryophyllum* in both trees. However, there was almost no congruency in the two trees on the evolutionary relationship among the African taxa.

5.2.12 Phylogeny and Chromosome Number

The findings of this study show that it does not follow that the species with basic number 2n = 34 are the primitive members of the group according to the phylogenetic tree even if the clades are rotated. Most of the clades have both diploid and polyploid taxa as postulated by Raadts (1989). According to her, the basic chromosome number for most of the east African taxa is 2n = 34 although some have 2n = 68, 2n = ca102 and 2n = ca126-135 (*K. boranae*) and 2n = 155-165 (*K. prittwitzii*). In 1984 Raadts recognized four taxa

i.e. *K. boranae*, *K. prittwitzii*, *K. germanae* and *K. marmorata* as distinct based on the account of chromosome numbers and vegetative characters. According to her *K. prittwitzii* combines taxa of different ploidy levels that make it a heterogeneous complex. She therefore separated two new species *K. germanae* and *K. boranae* based on morphological characters but also emphasized the fact that *K. germanae* was a more primitive member of the genus *Kalanchoe* (2n = 34) with *K. boranae* and *K. prittwitzii* forming a more derived group. This is not wholly reflected in the results of this study as *K. germanae* which is possibly more recent than the other two taxa but could hold for *K. prittwitzii* (2n = 155-165) which is more derived than *K. boranae* (2n = 126-135) although radiation seem to have taken place around the same time.

The second minor subclade (I2) within the sixth subclade consisted of taxa with 2n = 34 and 2n = 68 chromosomes while the rest of the clades had both diploid and polyploid states mixed for the East African species. It is therefore difficult to tell which group is more derived or primitive based on the present chromosome number because in the different clades there are diploid as well as polyploid species. As postulated by Uhl (1961), overlap in chromosome numbers and morphology suggest close relationships but at times data available may not be sufficient to draw valid conclusions. In this study the basal members of *Kalanchoe* happen to be closer to the Malagasy clade pointing to Madagascar as the center of diversification of the family which is not consistent with the cytology of the species sampled (Smith, 2023).

Raadts (1985) observed that chromosome number could be used to separate *K. lateritia* (diploid) and *K. crenata* (hexaploid) and their varieties. She further used both morphological intermediate characters and chromosome numbers to come up with three hybrids viz., *K. nyikae* ssp. *auriculata* × *K. glaucescens*, *K. rotundifolia* × *K. glaucescens*, *K. lateritia* × *K. crenata*. One of these hybrids *K. nyikae* subsp. *auriculata* × *glaucescens* was recently revisited by Smith and Figueiredo (2019) while *K. nyikae* subsp. *auriculata* is recognized as *K.* × *auriculata* based on its chromosome number (2n = 68) which differs from that of *K. nyikae* subsp. *nyikae* (2n = 34). In this study the two subspecies did not separate out as different entities early in time but late! They seem not to have evolved at the same time with *K. nyikae* subsp. *nyikae* likely to have been formed in a single event but *K. nyikae* subsp. *auriculata* possibly evolved at least more than once (I4a and I5a) and earlier in time. Their subspecies taxonomic level is therefore upheld according to the *FTEA* (Wickens, 1987) but more research needs to be done to clarify the taxonomic identity.

Based on chromosome numbers, some clades can have taxa that are very variable and confusing since not all the species have their chromosome numbers recorded (Mort *et al*., 2001) thus this study cannot draw a comprehensive conclusion on the correlation between chromosome numbers and phylogeny. It also follows that the taxa with the highest number of chromosomes are more or less ancestral than those with fewer chromosomes. Raadts (1989), noted that the characters of the small chromosomes in *Kalanchoe* are of limited taxonomic value which may also apply for the phylogeny. She also observed that there was no consistency between the *Kalanchoe* aggregates generic lines and the chromosomal

development of the group. This is reflected in the results obtained in this study for the infrageneric relationships.

Further, it was noted that cytological parallelism in *Kalanchoe* complicates its taxonomy for the cytological state is retained through asexual reproduction and that the subfamily Kalanchoideae might have originated from a hybridization event between two other subfamilies with subsequent amphidiploidy. However, further studies are required to clarify this relationship.

The basic chromosome number for most of the east African taxa in the genus *Kalanchoe* is 2n = 34 (*K. lateritia, K. lateritia* var. *prostrata, K. nyikae* subsp. *nyikae*). However, some have 2n = 68 (*K. nyikae* subsp. *auriculata*) and a few others have approximately 2n = 102 (*K. lateritia* var. *pseudolateritia*) (Raadts, 1989). On the basis of cytology, *K. lateritia* var. *pseudolateritia* can be separated from the other varieties of *K. lateritia* and *K. nyikae* subsp. *auriculata* from *K. nyikae* subsp. *nyikae* but this should not be solely used for taxon delimitation.

5.3 Ethnobotany of *Kalanchoe* in Kenya

Ethnotaxonomy and the ethnobotanical uses across different ethnic groups are discussed in this section.

5.3.1 Ethnotaxonomy of *Kalanchoe*

This study revealed that different ethnic groups in Kenya refer to *Kalanchoe* species generally at the level that corresponds to the genus of the scientific binomial system of plant names. Plants that are useful or culturally significant may have similar local names, particularly if they are similar in morphology or use. A similar ethnotaxonomy has previously been noted among the Kalenjins and Maasais, who apply the same name to taxa recognised as species in the scientific binomial system (Bjorå *et al*., 2015; Wanjohi *et al*., 2020). The use of markedly different names for the same species of *Kalanchoe* by the Luhya ethnic groups, show significant phonological variation in the names reflecting regional dialectal differences or language-specific phonetic shifts.

Vernacular names given to *Kalanchoe* plants are suggestive of how the plants are used and valued across communities but may be confused when translated to scientific names, particularly given the taxonomic complexity of *Kalanchoe* in the *FTEA* region, with numerous species forming complexes with ambiguous relationships. The linguistic similarities observed among the Luhya and Kisii suggest a common historical or cultural link influencing plant nomenclature. The distinct naming by the Kikuyu and other groups underscores the diversity in language evolution and plant perception across different communities. The Maragoli people's approach to differentiating *Kalanchoe* species based on morphological traits or toxicity is particularly notable, as it reflects an indigenous classification system that informs medicinal use. The designation of *K. crenata* as ‘male’ and *K. prittwitzii* as ‘female’ not only illustrates a cultural understanding of plant

characteristics but also has practical implications for their usage. The preference for *K. crenata* in external applications like sprains and massages, while *K. prittwitzii* is used both externally and orally for medicinal purposes, highlights the nuanced relationship between ethnobotanical knowledge and traditional healing practices.

The majority of names from western Kenya for example suggest that the plants are miraculous or magical thus may cure a wide range of illnesses including those connected to witchcraft as outlined in other studies (Milad *et al*., 2013; Assis de Andrade *et al*., 2023). Equally, species such as *K. prittwitzii, K. densiflora* and *K. lateritia* are also thought to cure diseases associated with witchcraft in Kenya, a fact that is noted by Pakia *et al.* (2003) and in Narok, *K. marmorata* is sown on graves. Outside of Kenya, *K. tetraphylla* H. Perrier is used to overcome challenging circumstances (Schmitz-Ruch, 1982), *K. paniculata* Harv. is used as a love charm (Akulova-Barlow, 2009) and *K. petitiana* is used to alleviate evil eye (Mekonnen *et al.,* 2013) hence the name miracle plant signifying the wide range of applications. For lightning protection and other disaster prevention, *Kalanchoe* are planted close to homesteads (Smith, 2017) since the plants have a cultural significance.

In some regions names such as "*plant of the leg*" or "*plant with water*" refer to the parts of the plant that are directly related to the purpose or the organ that the plant treats. However, some of the species like *K. crenata* are labelled by users as "poisonous" because of effects against pets, herbivores possibly causing abortion among humans by jeopardizing life as reported by Kokwaro (1976). Among the Mijikenda, apart from '*Gonzi chireka*', *K.*

lateritia is also known as "*Muchira-wa-ngozi*" (Pakia *et al.,* 2003) which is translated to 'the healer of the skin'.

5.3.2 Uses of *Kalanchoe* Species in Kenya

The ethnobotanical importance and usage levels of *Kalanchoe* species in Kenya highlight diverse patterns of utilisation and cultural relevance across different communities. The highest levels of usage and citation of *K. densiflora* and *K. prittwitzii* reflect their widespread recognition and multifunctionality in ethnobotanical practices. Their relative prominence in the dataset depicts their critical role in addressing medicinal and other local needs.

Conversely, the minimal or no documented usage of species such as *K. laciniata* and *K. mitejea* from the study indicated limited awareness or functional applications within the surveyed communities as *K. laciniata* has some of its uses documented elsewhere (Gouri *et al*., 2021; Stefanowicz-Hajduk *et al*., 2022). The findings reflect regional or cultural differences in plant knowledge or accessibility and suggest potential gaps in the documentation or understanding of these species' uses. In addition, species like *K. glaucescens* and *K. nyikae* also exhibit relatively low citation and use values, further emphasizing the uneven distribution of ethnobotanical knowledge among the species studied.

Overall, the data emphasises the importance of a few highly utilized species while revealing a broader spectrum of underutilized or less recognized plants. The disparities in

usage levels and citation frequencies suggest that community awareness, specific cultural practices, and ecological factors may significantly influence the perceived importance of these species.

The biocultural value of *Kalanchoe* species in Kenya is evident from the use of several species as herbal medicines in treating a wide range of illnesses in humans and other animals. This study corroborates previous reports on the therapeutic benefits of *Kalanchoe* (Richwagen *et al.,* 2019; Nascimento *et al.,* 2023). People normally collected the plant material they need from wild populations, as also noted by Misonge *et al.* (2023) thus implying that availability is a major influence on the species choice. For instance, the people in Taita Taveta and Kwale primarily use *K. lateritia* and *K. obtusa* while communities in Western Kenya largely use *K. prittwitzii, K. crenata,* and *K. densiflora.* This scenario has been interpreted as the interchangeability of *Kalanchoe* species (Hosomi *et al.,* 2022; Saravanan *et al.,* 2022) and does suggest that species that are most abundant and accessible find most usage.

Species such as *K. lanceolata, K. crenata*, *K. pinnata* are among the *Kalanchoe* species used for medicinal purposes not only in Kenya but elsewhere in Africa and other continents as noted in other studies (Gouri *et al*., 2021; Stefanowicz-Hajduk *et al*., 2022) indicating their global utilization. While *K. lanceolata* and *K. glaucescens* are primarily used as ornamentals in Kenya, they are used to treat infections in Uganda and Tanzania (Chhabra *et al.,* 1987). Even though *K. glaucescens* was documented by Maundu *et al.* (2001) as an analgesic in Kenya, respondents in this study did not mention the use.

The most commonly utilised *Kalanchoe* species in Kenya are the native and widely distributed species; *K. densiflora, K. prittwitzii, K. crenata, K. lanceolata,* and *K. lateritia* and had the highest number of uses. However, not all widely distributed species were highly used such as *K. lanceolata* and *K. glaucescens*. In comparison to the more widespread species, *K. obtusa* found in only one *FTEA* region, has a moderate number of known uses. An interesting observation from this study is that one of the most studied and beneficial species, *K. pinnata* which happens to be a roadside non-native plant in Kenya, is used exclusively to cure injuries locally but it is a cure for a wide range of diseases globally (Biswas *et al*., 2021; Singh *et al*., 2022). *Kalanchoe* species found in Kenya are utilised in different ways;

Kalanchoe ballyi which could not be traced in some of its known localities is reported as "chest medicine" for treatment of respiratory ailments (Jeffrey (n.d.) in Raadts, 1977), highlighting the need for documentation and sustainable utilisation of medicinal plants.

Kalanchoe citrina is primarily used for treating stomach aches and as an antimicrobial agent in poultry. Grade *et al*. (2009) documented its use in wound healing in livestock in Uganda, while Ichikawa (1987) highlighted its religious significance in alleviating evil spirits. The plant's stems are also used to make flutes in Kenya, underscoring its cultural importance. However, its absence in cultivation suggests it is not a primary medicinal resource within the communities where the field survey was carried out.

Kalanchoe crenata, a widely utilized medicinal plant across Africa and beyond, holds a prominent position in traditional healthcare systems due to its versatile applications. It is used for treating a myriad of ailments, including wounds, sprains, stomachaches, respiratory disorders, and genitourinary issues. Traditional preparation methods such as burning leaves on charcoal or applying extracts highlight its practicality and effectiveness, particularly in addressing antiseptic and anti-inflammatory needs, as supported by Adjanohoun *et al*. (1996). Its use extends to specific conditions such as hypomenorrhoea, convulsions, rheumatism, asthma, diabetes, and kidney diseases, reflecting its broad therapeutic spectrum. The plant's role in managing pain, infections, and chronic diseases such as HIV/AIDS further underscores its medicinal value. In various African communities, it serves as a remedy for childhood ailments, helminth infections, and even labor induction in humans. Its potential as a standardized treatment for conditions like diabetes, arthritis, and neuropathic pain is supported by scientific validation of its anti-inflammatory, analgesic and antiarthritic properties (Dimo *et al*., 2006; Ngueleface*k et al*., 2006). Moreover, its cardiac benefits, ornamental appeal, and genetic diversity enhance its status as a critical resource in both traditional and modern medicine. This diverse applicability, coupled with cultural significance, underscores the need for further exploration of *K. crenata*'s pharmacological potential.

Kalanchoe densiflora is a widely utilized medicinal plant in Kenya, renowned for its efficacy in treating an array of human and veterinary conditions as documented in this study. Extensively used for stomach aches, diarrhea, rheumatism, and as an antibiotic in

poultry, its antiseptic and anti-inflammatory properties make it vital for managing skin rashes, insect stings, and wound healing, supporting what was reported in previous studies (Kokwaro, 1981; Maundu *et al*., 2001; Odongo *et al*., 2018). This species is integral in traditional medicine among the Kalenjin, Kikuyu, and Maasai communities, treating ailments such as toothaches, swollen organs, rheumatism, and umbilical hernias, as well as enhancing general well-being which is in line with Njoroge and Bussmann, 2006's findings. Beyond medicinal use, its cultural importance is evident in rituals and artifacts, such as flutes among the pastoral communities as observed by Ichikawa (1987) among Suiei Dorobo people. In Tanzania and Uganda, its applications span wound care, inflammation, malaria, tuberculosis, and even immune stimulation (Tabuti *et al*., 2010; Nalumansi *et al*., 2014). Research highlights that it has antibacterial properties, antioxidant and anti-inflammatory properties (Kirui *et al*., 2014; Odongo *et al*., 2017). Its steroidal alkaloids are identified as promising agents for cancer treatment (Odongo *et al*., 2017). The versatility of *K. densiflora* in addressing health, veterinary, and cultural needs support its significance as a valuable ethnobotanical resource in East African communities.

Kalanchoe germanae did not record any use in this study but a study by Kipkore *et al*., (2014) indicates its use as an analgesia and ganglion remover by the Marakwet in Rift valley.

Kalanchoe glaucescens is primarily valued as an ornamental plant; however, research highlights its significant medicinal applications. Studies indicate its use in treating rheumatism (Glover *et al*., 1961, as cited in Nankaya *et al*., 2020), alleviating pain as an

analgesic (Maundu *et al*., 2001), and facilitating massage therapy. In Uganda, it is traditionally used to combat bacterial infections, including tuberculosis, and to manage respiratory ailments such as coughs. Additionally, it is used to promote the rapid healing of the umbilical cord in newborns (Bunalema *et al*., 2014; Tugume *et al*., 2016). Beyond its medicinal benefits, the plant holds promise as an ornamental flowering potted plant (Currey and Erwin, 2011).

Kalanchoe lanceolata is a widely recognized ornamental and medicinal plant for treating arthritis, injuries and skin infections. Different communities in Kenya use it for stomach upsets, malaria, liver and spleen conditions, and as a blood cleanser as highlighted by Kigen *et al*. (2017). In Tanzania it is used as an analgesic and for rheumatism treatment (Raadts, 1977). Outside East Africa, in countries like Nigeria, it is additionally used to treat headaches and neck pain, dysentery wounds, fever, microbial infections and in witchcraft practices (Suram *et al*., 2024). Some of these diverse applications align with informants' feedback from our study.

Kalanchoe laciniata was not reported for any specific use in the present study. However, previous research highlights its medicinal applications among the Maasai communities in both Kenya and Tanzania and globally (Manan *et al*., 2016; Sharif *et al*., 2017). According to Glover and Samuel (n.d.), as cited in Raadts (1977), and Fernandes *et al*. (2019), the plant has been traditionally used to treat abnormal swellings, injuries and other diseases, suggesting its significance in indigenous healthcare practices. This traditional knowledge shows the plant's potential therapeutic value and the need for further pharmacological

studies to validate its medicinal properties. Beyond its ethnomedicinal applications, *K. laciniata* also holds ornamental value (Laskar *et al*., 2023), it has potential as a flowering potted plant, which could make it a desirable addition to horticultural markets. Its aesthetic appeal, combined with its resilience, may contribute to its commercialization in ornamental plant trade. This dual functionality—both as a medicinal and an ornamental plant—demonstrates the importance of further research on its cultivation, usability, and conservation to maximize its benefits across different sectors.

Kalanchoe lateritia is a resourceful plant valued for its medicinal, cultural, and scientific applications. Traditionally, it is used to treat skin infections, coughs, swollen spleens, epilepsy, convulsions, microbial and helminthic infections, and to manage fever and injuries. Communities in Kenya also employ it for labor induction and as a remedy for childhood ailments such as whooping cough, as reported by Waisindye *et al*. (2016) for Uganda. Among coastal Kenyan communities, it holds cultural significance, being used in religious and ritual ceremonies for spiritual protection, tribal cleansing, and averting witchcraft. Additionally, the plant serves as a vegetable and an ornamental species, enhancing its utility. Scientifically, it plays a role in research on interspecific hybridization, nitrogen nutrition, and CAM photosynthesis, contributing to advancements in botany and the cut flower industry. These uses underscore its importance, blending indigenous knowledge, cultural practices, and modern scientific exploration as reports from other studies also indicate (Adjanohoun *et al*., 1996; Kamatenesi-Mugisha *et al*., 2008).

Kalanchoe marmorata is an ornamental plant that is traded on a small scale in tree nurseries. It is also mainly used for treating injuries and as analgesic but studies indicate its use in treating unspecified medical disorders and as a charm for good luck (Gardener (n.d.) in Raadts, 1977). The Maasais in Kenya attach cultural value to the plants by planting them on graves. Outside Kenya, it is an antiseptic and anticancer (Ssegawa and Kasenene, 2007; Singab *et al*., 2012) due to its phenolic content, a property that has also been noted in *K. delagoensis* (Stefanowicz-Hajduk *et al*., 2020). It is cultivated as a potted and garden plant and traded (RHS, 2021 cited in Kahraman *et al*., 2022) an indication that it is underutilized in the country.

Kalanchoe mitejea is used in treatment of fractures and sprains as Okello *et al*. (2010) also points out and as an ornamental plant as observed by (Timberlake 1987 in Timberlake, 1994). The plants were found growing in bushes some which are used for beekeeping indicating their role in nectar provision due to their dense inflorescence. Their numerous robust succulent leaves could possibly be a good source of medicine, an area that needs to be explored.

Kalanchoe obtusa is endemic to Kenya's coastal region, where the Duruma use it as a pesticide and for treating infections and children's diseases (Pakia *et al*., 2003). This study confirmed these uses.

Kalanchoe pinnata originally from Madagascar and now naturalised in Kenya was reported in this study to have a restricted medicinal use, limited to the treatment of injuries.

However, it is widely used elsewhere: in Tanzania for rheumatism (Clack, 2009) and in Uganda for various ailments, including malaria and HIV/AIDS (Gumisiriza *et al*., 2019; Anywar *et al*., 2020). It also has pharmacological properties including, antibacterial, anticonvulsant and antitumor (Sharker *et al*., 2012).

Kalanchoe prittwitzii is a multifunctional plant valued for its medicinal, ornamental, and cultural significance, particularly in Kenya and neighboring regions. Known for treating skin rashes, backaches, hernia, and serving as an antiseptic, its applications extend beyond medicine to include uses like providing shade, firewood, and cultural artifacts, such as woven masks for boys during circumcision ceremonies. This integration into daily and ceremonial life underscores its deep-rooted cultural relevance. Ethnobotanical surveys in Kenya reveal that local knowledge of *K. prittwitzii*'s uses surpasses what is documented, highlighting its significance in areas where it is prevalent. In western Kenya, the plant is distinguished by its pale green, salty-tasting leaves, which coexist with *K. crenata*. Beyond its medicinal utility, it is an easily induced ornamental flowering plant, appreciated for its aesthetic appeal. It also serves as fodder and is used to manage digestive disorders in children, as observed in Tanzania (Timberlake, 1994). The plant's adaptability and diverse uses emphasize its importance to both humans and livestock in the regions where it thrives, revealing its underexploited potential.

Kalanchoe nyikae is mainly ornamental but studies indicate its use in breeding for cut flowers (Currey and Erwin, 2011; Chang *et al*., 2018; Kuang *et al*., 2021) supporting its potential as a potted ornamental plant.

5.3.2.1 Medicinal Uses of *Kalanchoe* in Kenya

This study revealed the extensive therapeutic applications of *Kalanchoe* species as multifaceted medicinal plants addressing numerous health conditions including injuries, swellings, hernias and general pain relief. The broad spectrum of pharmacological activities including bacterial, fungal, viral, protozoan, parasitic, provide remedies for digestive, respiratory, skin, musculoskeletal and reproductive health issues like stubborn pregnancy and labour induction in humans. Their potential as anti-inflammatory, analgesic, and anticancer agents has been emphasized, agreeing with Milad *et al*. (2013). Additionally, it confirmed the use of *Kalanchoe* extracts in insect bite treatments, blood cleansing, and combating microbial illnesses in poultry, as initially documented by Kokwaro (1976; 1981). Although not always known to most traditional practitioners or the local communities utilizing herbal medicine from *Kalanchoe* extracts, the medicinal efficacy of *Kalanchoe* species possibly stems from their phytochemicals, including steroids as has also been highlighted by Choudhury *et al*. (2015) and Fernandes *et al*. (2019). The steroid hormones which possess anticancer properties are the possible component responsible for the application of *Kalanchoe* in the treatment of cancer related ailments mentioned by respondents, enhancing their value as a medicinal resource for chronic diseases not only in Kenya but globally, a fact noted by Kolodziejczyk-Czepas and Stochmal (2017).

Kalanchoe species documented varied in preparation methods including chewing, warming leaves on charcoal, crushing to obtain extracts, boiling, mixing with other ingredients and

topical massage. These findings demonstrate the strong reliance on simple, accessible and largely non-mechanized preparation techniques within traditional healing systems, highlighting both the versatility of *Kalanchoe* species and the adaptability of local medicinal knowledge. Traditional applications involve using crude leaf extracts or sap, either applied externally or ingested orally, agreeing with methods highlighted by Kolodziejczyk-Czepas *et al*. (2017). These findings align with contemporary studies and confirm the therapeutic potential of *Kalanchoe* species such as *K. densiflora*, *K. crenata*, *K. lanceolata*, and *K. pinnata* (Fernandes *et al*., 2019; Molina *et al*., 2019). Notable findings include the identification of *K. prittwitzii*'s broad applicability across several health issues, while other species such as *K. laciniata* and *K. lanceolata*, which are primarily ornamental in Kenya, are used medicinally in neighbouring countries. These findings underscore the significance of *Kalanchoe* as valuable medicinal plants with applications in both human and poultry medicine and highlights underexplored and underutilized medicinal potentials in Kenya.

The findings point to the importance of *Kalanchoe* species as a readily available, cost-effective, and culturally significant medicine. The medicinal properties, attributed to bioactive compounds such as bufadienolides (Kolodziejczyk-Czepas and Stochmal, 2017), support their use in traditional medicine and suggest their potential for integration into modern medical practices. The study also draws attention to species-specific applications, such as *K. crenata*'s role in reproductive health and *K. prittwitzii*'s broader utility in managing pain, infections, and immune responses. However, challenges such as potential

toxicity and the lack of comprehensive pharmacological studies on these species necessitate further research to validate and optimize their safe application.

The findings corroborate existing research on the medicinal applications of *Kalanchoe* species in different regions, aligning with studies that highlight their efficacy in treating infections, skin conditions, and musculoskeletal disorders (e.g., da Silva *et al*., 2018; Fernandes *et al*., 2019). Additionally, the identification of *K. prittwitzii* as an important resource echoes similar discoveries in underexplored species globally. Variations in the documented uses of species like *K. laciniata*, *K. crenata*, and *K. pinnata* between Kenya and other regions (Asiedu-Gyekye *et al.,* 2022; Bopda *et al.,* 2021), points out the influence of cultural practices and environmental factors on medicinal applications. These findings reinforce the global relevance of *Kalanchoe* species in traditional medicine while highlighting gaps in knowledge, particularly in pharmacological profiling and therapeutic standardization.

5.3.2.2 Other Uses of *Kalanchoe* in Kenya

Beyond their well-documented medicinal applications, *Kalanchoe* species in Kenya serve a variety of cultural, environmental, horticultural, and nutritional purposes. Socially, these plants hold deep traditional and mystical significance. For example, *K. prittwitzii*, *K. densiflora*, and *K. lateritia* are believed to counteract ailments associated with witchcraft, a belief consistent with previous studies (Pakia *et al*., 2003). Similarly, *K. paniculata* and *K. petitiana* are used as love charms and protective amulets against the evil eye in other regions (Akulova-Barlow, 2009; Mekonnen *et al*., 2013).

In Kenya, *K. marmorata* is commonly planted on graves in Narok, signifying its role in funerary traditions. Additionally, various *Kalanchoe* species are cultivated near homesteads, often under the guise of being ornamental plants. However, as Smith (2017) suggests, their placement may be linked to beliefs in disaster prevention and spiritual protection, underscoring their cultural importance.

Environmentally, *Kalanchoe* plants have practical uses that reflect their adaptability. They are employed as boundary markers, sources of fuel, and shade providers for both people and livestock. New findings indicate their use in making herbal soap, flutes, whistles, and masks, as well as for personal hygiene, including general and anal cleanliness. These applications reveal their ecological relevance and adaptability to human needs in diverse contexts, particularly in Kenya.

In horticulture, *Kalanchoe* species are globally renowned as ornamental plants due to their attractive nature, low water requirements, and easy maintenance (Kołodziejczyk-Czepas and Stochmal, 2017; Kahraman *et al*., 2022). However, in Kenya, the ornamental use of these plants is relatively limited, with species like *K. marmorata* which are sold on small scale in tree nurseries in Nyandarua and planted in gardens in Western Kenya offering untapped potential for the flower industry (Smith and Figueiredo, 2020). Several species, such as *K. glaucescens*, *K. pinnata*, and *K. marmorata*, are planted as ornamental plants, particularly near homesteads, hospitals, and graveyards in areas like Narok. These species contribute to aesthetic and ecological benefits, such as preventing soil erosion. Breeding trials involving *K. citrina*, *K. lateritia*, and *K. nyikae* (Kuang *et al.,* 2021) have shown

promise for expanding the horticultural applications of *Kalanchoe* in Kenya, presenting opportunities for economic growth in this sector.

Nutritionally, *Kalanchoe* plants have demonstrated potential as a source of food and antioxidants. In Kenya, the leaves of species such as *K. prittwitzii* and *K. lateritia* are chewed as thirst quenchers, particularly in arid regions or during dry seasons. Additionally, species like *K. laciniata* and *K. pinnata* are rich in vitamins C and E, making them valuable in human diets (Milad *et al*., 2013; Zawirska-Wojtasiak *et al*., 2019). Their antioxidant properties, attributed to flavonoids and phenolics, further enhance their nutritional significance. While their medical applications are widely studied, there remains an untapped potential for exploring their broader nutritional benefits, warranting further research and awareness.

5.3.3 Use of *Kalanchoe* Species in Relation to Distribution

The distribution of *Kalanchoe* species across Kenya influences their ethnobotanical significance. Widely distributed species like *K. prittwitzii* and *K. densiflora* exhib higher frequencies of use, suggesting ecological availability enhances familiarity and integration into local medicinal practices.. This aligns with the observation that community exposure often shapes ethnobotanical knowledge and utilisation pattern. However, distribution alone does not determine cultural importance. Some fairly widely distributed species such as *K. glaucescens*, show limited use. While others with restricted distribution, such as *K. obtusa*, remain highly valued for specific medicinal or cultural purposes. This variability reflects the complex interplay between ecological accessibility cultural preferences and

perceived therapeutic efficacy. The extensive use of certain species, particularly *K. prittwitzii*, highlights their potential for pharmacological research and the importance of conservation efforts to prevent overharvesting, a move that is support by Shafi *et al*., 2021.

5.4 Threats to *Kalanchoe* Species, Conservation Status and Perceived Rarity

Kenya harbors about 76% of the East African native *Kalanchoe* representatives, with some species being endemic to the environmentally degraded coastal regions. As confirmed in this study, threats to *Kalanchoe* species are alarming, *K. fadeniorum*, *K. ballyi* and *K. bipartita*, for instance, have not been traced in their presumed habitats, highlighting a critical conservation gap regarding these ornamental succulents. The decline in coastal habitats and their associated biodiversity, *Kalanchoe* included, was earlier noted by Ngumbau *et al*. (2020). Threats, conservation status and perceived rarity are discussed in this section.

5.4.1 Threats and Perceived Rarity

The main threats to *Kalanchoe* species, like most vascular plants, include habitat loss and fragmentation due to human activities—agriculture and infrastructure development—as well as climate variability were evident in all study localities, aligning to other studies (Smith *et al*., 2019; Kumari *et al*., 2020). Most of the threats were evenly spread across the study sites except flooding that was specific to Narok, fires and drought in Eastern and coastal Kenya.

Fourteen *Kalanchoe* species in Kenya are considered of little concern based on their extent of occurrence (EOO) as revealed by the GeoCAT assessment results. However, their area of occupancy (AOO) is under threat due to the aforementioned factors, which have significantly impacted their habitats as land changes occur. Many species, particularly in the Western, Coastal, and Rift Valley regions, are naturally rare, and their forested habitats are rapidly disappearing or fragmenting. Although *Kalanchoe* species exhibit drought tolerance, this study observed the effect of erratic climate variability and shifting ecological conditions especially in the eastern and coastal regions which affect the distribution and flowering cycles off the plants (Kumari *et al*., 2022; Kumar *et al*., 2024).

Beyond environmental factors, threats to *Kalanchoe* species are exacerbated by historical influences, accessibility issues, and disparities in conservation investment and stakeholder engagement as noted not only in this study but also other studies (Timberlake and Golding, 2006; Githitho, 2021). Walter and Gillett (1998) emphasized the need for updated conservation assessments for several East African *Kalanchoe* species, such as *K. lateritia*, *K. nyikae* (Kenya, Tanzania), *K. obtusa*, *K. ballyi*, *K. fadeniorum*, and *K. densiflora*, which was done two decades later. Reports indicate that *K. ballyi*, once common in coastal forests, has not been collected since 1950 (Raadts, 1977), reinforcing the urgency for updated Red List. The assessment results from this study confirm the critically endangered status of three species, endangered status of 12 and the vulnarability of four.

5.4.1.1 Anthropogenic Activities and Urgency of Conservation Measures

This study revealed the endangered status of most *Kalanchoe* species in Kenya, calling for urgent action to list the taxa in the Red List of endangered plants. Delayed conservation efforts can result in species extinction. For instance, *K. fadeniorum* was declared extinct in the wild due to agricultural encroachment at its only known habitat in coastal Kenya along Mackinnon Road (IUCN, 2025). The species was last observed in 1977 and has since disappeared. However, it is conserved in five *ex-situ* collections as noted in IUCN (2025), underscoring the importance of botanical conservation initiatives. Similarly, *K. ballyi* has disappeared from disturbed roadside areas and has declined in the Arabuko Sokoke Forest, raising concerns about its survival (Mwangoka *et al*., 2022 in IUCN, 2025). While *K. bipartita* has not yet been placed on the Red List, its population status remains uncertain, particularly in Embu (Dr. Paul Kirika, pers. comm.).

Urbanization and infrastructural expansion have further reduced forested areas, threatening *Kalanchoe* species. Conservation efforts face additional challenges due to the declining interest of younger generations in indigenous plant knowledge, legal constraints affecting herbalists, overexploitation, fires, and the irresponsible use of agricultural chemicals and nonbiodegradable materials.

In coastal forests such as Kilibasi, Arabuko Sokoke, Mangea Hill, and Medium Kwale, biodiversity loss is accelerating due to inadequate management and population pressures (Schürmann *et al*., 2020). The Mau Forest, a critical habitat for *Kalanchoe* and other succulents, is threatened by deforestation, illegal logging, agricultural encroachment,

tourism, urbanization, grazing, and mining leading to loss of the biodiversity (Fungomeli *et al*., 2020; Schürmann *et al*., 2020).

5.4.1.2 Climate Variability and Natural Disasters

The absence of *Kalanchoe* species in historically recognized sites such as Voi Hills, Mackinnon Road, Arabuko Sokoke Forest, and Kilibasi suggests heightened threats from habitat loss. Even species with broader distributions, like *K. lateritia* and *K. lanceolata*, may be affected by declining coastal forests. Kilifi County alone lost 7.23 kha of natural forest, impacting *Kalanchoe* habitats (Robertson and Luke, 1993; Githitho, 2021). Notably, only 14% of the approximately 175 *Kalanchoe* species have been assessed for the IUCN Red List, underscoring the need for updated conservation evaluations.

While human settlement and agriculture contribute significantly to habitat loss, prolonged droughts and flooding—intensified by climate variability—may pose even greater threats. Narok River frequently floods, breaking its banks, devastating resident flora, including *Kalanchoe* species supporting earlier reports (Opere and Ogallo, 2006; Marie Mireille *et al*., 2019). Changes in land use due to industrialization and farming further exacerbate flood risks in Narok and other visited regions (Marie Mireille *et al*., 2019; Tonui, 2021). The Kenyan government has responded by promoting afforestation and climate change awareness, exemplified by the Climate Change Amendment Bill 2023 (Abel *et al*., 2023), which designated November 10th as a national tree-planting day to support Vision 2030 (Owoeye *et al*., 2019; Detelinova *et al*., 2023).

Given the recent extreme weather events—prolonged droughts and floods—Kenya's vegetation, including *Kalanchoe* species, faces severe threats. Chyulu Hills forest fires have further compounded these challenges (Kamau and Medley, 2014; Henry *et al*., 2024) as observed during field work. Protecting chemically significant yet endangered *Kalanchoe* species requires urgent research and conservation measures as Pattewar (2012) also observes.

5.4.2 Conservation Status of *K. lateritia, K. nyikae* and Other Species of *Kalanchoe*

This study confirmed the threatened status of *Kalanchoe* species endemic to East Africa as critically endangered waranting urgent conservation efforts for these species. The species threat status as per the IUCN Red List (2025): *K. obtusa* (Kenya, Tanzania) is classified as vulnerable (VU), *K. fadeniorum* (Kenya) as extinct in the wild (EW), *K. ballyi* (Kenya) as endangered (EN) (IUCN, 2025). Twelve species are endangered and four vulnerable.

The study also confirmed that neither *K. lateritia* nor *K. nyikae* species as a whole fall into the Least Concern category, contrary to previous evaluations (IUCN, 2025). Both *K. lateritia* and *K. nyikae* are endemic to East Africa, specifically Kenya and Tanzania, and exhibit highly restricted distributions. Among them, only *K. lateritia* var. *lateritia* has a relatively wider range. The reassessment highlights that all these taxa meet the IUCN Endangered (EN) criteria, particularly due to their low Area of Occupancy (AOO <500 km²) and Extent of Occurrence (EOO <5000 km²), as determined using the GeoCAT tool (IUCN, 2025). According to the study, the conservation status of *K. lateritia* var. *prostrata* and *K. lateritia* var. *pseudolateritia*, is Endangered as opposed to the earlier state as

Vulnerable and Data Deficient (DD) respectively. The Data Deficient (DD) status hindered informed decisions on the conservation status and decision regarding species that fall in this category. *K. lateritia* var. *pseudolateritia* is almost becoming extinct in the wild if no action is taken in the near future to protect the plants.

Additionally, other East African *Kalanchoe* species, such as *K. peteri* and *K. usambarensis* (Tanzania), also face similar threats and are classified as Endangered (EN) primarily due to land conversion for agriculture (IUCN, 2025). This trend indicates a widespread pattern of habitat degradation affecting the region's endemic flora. Given the increasing threats posed by agriculture, construction, quarrying, and habitat fragmentation, urgent conservation measures are required. These should include habitat protection policies, reforestation programs, regulation of land use, and public awareness initiatives. Furthermore, continuous monitoring and taxonomic studies will be essential in ensuring the long-term survival of these endemic species.

This study aligns with the IUCN (2025) recommendation to update the conservation status of *K. lateritia* and *K. nyikae* and do comprehensive reassessment and update the other species listed in Appendix 1 as requiring conservation assessment update. The findings reinforce the urgent need for conservation interventions to mitigate the ongoing decline of these species and their habitats. The IUCN Red List promotes revisiting taxa and evaluating variations and subspecies while adhering to the same standards as species assessments as done in this study and emphasised by other authors (Betts *et al.,* 2020; Cazalis *et al.,* 2024).

Since the taxa are threatened, the questionable taxonomic status of *K. nyikae* followed the *FTEA* for comparative and monitoring purposes. With the taxa being reassessed as Endangered, the study satisfies the IUCN's (2025) recommendation for an update of the conservation status of *K. lateritia* (Beentje, 1994) and *K. nyikae* (currently, *K. nyikae* and *K. auriculata* (Mwangoka *et al.*, 2022 in IUCN, 2025) as least concern (LC).

5.4.3 Prospects for the Conservation of *Kalanchoe* and Role of Indigenous Knowledge in Sustainable Plant Use in Kenya

Due to increased human population and anthropogenic effects arising from the need for food, settlement and infrastructure, many *Kalanchoe* and other plant habitats have been severely fragmented or completely destroyed, as outlined earlier. Conservation of these species therefore requires a balanced approach that integrates both *in-situ* and *ex-situ* strategies. For *Kalanchoe* species, this may involve strengthening the management of protected areas, community conservancies, and sacred groves where these plants naturally occur. Integrating local communities into habitat restoration, sustainable land-use planning, and ecological monitoring can enhance protection while promoting livelihood co-benefits. Additionally, the establishment of habitat corridors and strict control of land conversion in biodiversity hotspots are crucial to maintaining viable populations in the wild.

On the other hand, *ex-situ* conservation provides a critical safety net for species already threatened in their natural habitats. This includes the propagation and maintenance of

Kalanchoe species in botanical gardens, seed banks and research institutions. Such facilities can serve as genetic reservoirs for future reintroduction and rehabilitation programs. Tissue culture and other biotechnological methods could also be explored to conserve rare genotypes and ensure genetic diversity. Furthermore, partnerships between universities, conservation agencies and local botanical gardens can enhance capacity for large-scale propagation, documentation and dissemination of indigenous species. Some of these strategies are in place; however, their effectiveness remains limited.

The success of both *in-situ* and *ex-situ* initiatives depends on robust awareness and education programs. Strengthening formal and informal education to highlight the ecological, cultural and medicinal value of *Kalanchoe* can foster public participation and stewardship. Integrating conservation topics into local curricula, promoting citizen science and recognizing community custodians of indigenous knowledge will reinforce conservation ethics and ensure the long-term sustainability of these valuable species.

Amidst challenges of life and increasing demand for land use, some communities in Kenya provide for their people without destroying the environment. In Taita Taveta, Ngangao forest and its surroundings are fairly well conserved through concerted efforts of the locals and the governments in addition to non-governmental organizations. Here, the locals look for alternative and sustainable means of survival like agriculture and honey to reduce over-reliance on materials that come from the forest like timber and charcoal among others, hence the current improved conservation status (Mwadime and Joram, pers. Comm., 2019).

The Ogiek, being populations that rely heavily on forests for subsistence, found within the Mau complex as well as in Mount Elgon forests have also devised creative ways not to cut down trees for whatever purpose i.e. firewood or even making bee hives but only to use trees that have fallen down by themselves any violators are cursed by the elders. Equally they don't plant any crops within the forest. While picking plant parts for use as medicine, just enough for the health condition at hand is picked and if it is from the roots then only one of it is extracted and soil is put back after the process. Such practices are thought to have led to their enhanced ability to sustainably use the natural resources within their reach and without overexploitation (Dr. Denis Misiko Mukhongo, pers. Comm., 2024).

From these two case scenarios, the study recommends that cultivating such a culture of sustainable use for the available natural resources be they plants, animals etc. in other communities that have vital plants but at risk of extinction could help alleviate the situations.

5.4.4 Invasiveness and the Weedy Nature of *Kalanchoe*

Kalanchoe species, particularly *K. lanceolata*, *K. densiflora*, and *K. glaucescens*, have formed weedy populations in parts of Kenya, especially within the Rift Valley as reported in this study. Additionally, Madagascan species, such as *K. pinnata* and *K. daigremontiana*, have been naturalized in Kenya but their use is limited as compared to what has been documented globally. The naturalisation is also in South and western Africa and it is mainly due to their adaptability in propagation and ease of cultivation (Herrera *et al*., 2018; Smith *et al*., 2019; POWO, 2025). Understanding the invasiveness and

horticultural characteristics of *Kalanchoe* is crucial for developing management and conservation strategies (Smith, 2022). While these plants are valued for their aesthetic and therapeutic properties, their uncontrolled spread raises concern about ecological balance.

Several invasive *Kalanchoe* species, including *K. lanceolata*, *K. densiflora*, and *K. pinnata* are recognized for their medicinal uses (Vargas *et al*., 2022), the species can be managed and utilized in traditional medicine. These plants thrive in disturbed habitats like forest edges, roadsides, and homesteads (Agnew, 2013), along Nakuru-Nairobi road *K. densiflora* populations are reducing with the thriving of the roadside bushes. Despite concerns over their invasiveness, *Kalanchoe* species remain popular in horticulture, with their high market demand driven by their diverse floral structures, colors, and propagation ease, with plantlets growing from leaves (Descoings, 2003; Kahraman *et al*., 2022).

Due to their aesthetic appeal and propagation versatility, *Kalanchoe* can be cultivated for ornamental purposes which could possibly boost the Kenyan floral industry. Research in Nairobi gardens identified 19 cultivated *Kalanchoe* species, but only two—*K. marmorata* and *K. nyikae* subsp. *nyikae*—are native to East Africa (Newton and Mbugua, 1993). However, experts caution against cultivating exotic species that could become naturalized and disrupt local ecosystems (Van der Burg *et al*., 2012). While careful cultivation of wild *Kalanchoe* in gardens can support conservation and provide robust ground cover, it is essential to manage their spread responsibly to balance their benefits with potential ecological risks (Dr. Itambo Malombe, pers. comm., 2024).

5.4.5 Youth Involvement in Ethnobotany and Conservation of *Kalanchoe* in Kenya

The participation of Kenyan youth in ethnobotanical studies and biodiversity conservation is crucial for fostering sustainable resource management. However, their engagement and level of knowledgeability in ethnobotanical uses of plants, particularly concerning *Kalanchoe* species, remains limited. Addressing this gap requires deliberate strategies that integrate youth into conservation efforts through policy formulation, environmental awareness, and the implementation of legal frameworks that mandate their active participation. Instilling a sense of responsibility and ensuring the continuity of traditional botanical knowledge can possibly be done by actively engaging them in conservation strategies, including ethnobotanical studies of plants within the Kenyan flora.

They should also be allowed to voice their concerns regarding community environmental challenges without being victimized as such approaches have been successful in countries such as Italy and various Asian nations, where youth are actively involved in conservation initiatives (Baring and Molino, 2021; Wardhana *et al*., 2022). Youth possess a unique ability to address the consequences of human-induced climate change due to their awareness of anthropogenic environmental impacts and their strong connection to sustainability efforts (Riemer *et al*., 2014; Gielen and Lowrey, 2022). Strengthening youth participation in conservation programs will not only enhance biodiversity conservation but also empower them as key stakeholders in sustainable utilisation of resources.

5.5. Hypotheses

Hypothesis One was accepted. The study found that morphological variation among Kenyan *Kalanchoe* species is not fully congruent with molecular phylogenetic relationships within the *K. lateritia* and *K. nyikae* species complexes. Molecular data provided higher-resolution insights into the evolutionary relationships among these taxa, supporting the taxonomic revision of *K. lateritia* varieties and *K. nyikae* subspecies.

Hypothesis Two was also accepted. Molecular phylogenetic analyses showed that Kenyan *Kalanchoe* species do not form monophyletic clades distinct from global *Kalanchoe* taxa. Instead, they are polyphyletic, clustering with other African species, which suggests historical gene flow and shared evolutionary lineages beyond Kenya.

Hypothesis Three was accepted. The study demonstrated that the diversity of documented ethnobotanical uses of *Kalanchoe* species in Kenya is significantly lower than the actual range of uses identified through community-based field surveys. This highlights gaps in existing literature and the importance of field-based ethnobotanical documentation.

Hypothesis Four was accepted. The conservation assessment revealed that all *Kalanchoe* species studied exhibit trends indicative of potential threat status under IUCN criteria. Consequently, three species were classified as Critically Endangered, twelve as Endangered, and four as Vulnerable, underscoring the urgent need for targeted conservation action.

5.6 Conclusions and Recommendations

5.6.1 Conclusion of the Study

This study explored the multifaceted significance of *Kalanchoe* species in Kenya by addressing their species boundaries, phylogenetic relationships, ethnobotanical value and conservation status, .

The first objective of the study was to delineate species boundaries within the *K. lateritia* and *K. nyikae* species complexes based on molecular and morphometric approaches. Results of the study revealed substantial genetic and morphological divergence, supporting the recognition of distinct lineages such as *K. nyikae* subsp. *auriculata* and *K. lateritia* var. *pseudolateritia*. These findings call for a taxonomic reclassification of certain groups and enhance our understanding of species diversity within Kenya's *Kalanchoe* flora, providing a stronger basis for conservation and sustainable use. Molecular and morphometric analyses enhanced the taxonomic resolution within the *K. lateritia* and *K. nyikae* species complexes leading to improved species delineation and conservation prioritization.

The second objective was to resolve phylogenetic relationships among the *Kalanchoe* species in Kenya. Phylogenetic analyses using molecular data affirmed the monophyly of *Kalanchoe* within the Crassulaceae family and suggested evolutionary patterns shaped by rapid radiation. Kenyan species were found to be more closely related to other African *Kalanchoe* taxa than to their Asian or Arabian counterparts, indicating a complex biogeographic history. Phylogenetic analyses confirmed the monophyly of Kenyan

Kalanchoe species and clarified their evolutionary relationships emphasizing their close biogeographic ties to African lineages.

The third objective of the study was to evaluate the ethnobotanical uses of *Kalanchoe* species in Kenya. Through extensive field surveys using interviews and questionnaires the study highlighted thirteen of Kenya's native *Kalanchoe* species are actively utilized by local communities in traditional medicine and cultural practices, particularly *K. prittwitzii*, *K. densiflora*, and *K. lateritia*. These species are commonly utilised in treating various ailments including injuries, gastrointestinal problems and infections in humans and in ethno-veterinary applications for infections in poultry, accentuating the importance of preserving both the plants and the indigenous knowledge systems associated with them. The study successfully documented several unique ethnobotanical uses of *Kalanchoe* species in Kenya, particularly within traditional medicine and cultural practices. These findings highlight the genus' distinctive role in primary health care and its promising potential for the floriculture industry. Unique uses that emerged from the investigation include: Specialized medicinal applications, such as the use of specific *Kalanchoe* species for treating ear infections, burns, wounds, stomach ailments, and inflammatory conditions—often through leaf sap, poultices, or decoctions. Culturally significant practices, including the use of *Kalanchoe* leaves in rituals for protection, smearing houses, circumcision, making flutes and musks. Use as a natural preservative or healing aid, where crushed leaves are applied to assist in the healing of umbilical cords in infants or to enhance recovery from livestock ailments—uses that are not widely documented outside

local Kenyan contexts. Horticultural and floriculture potential, as some species are valued for their drought tolerance, ornamental appeal, and ability to thrive in varied environments, making them suitable candidates for commercial cultivation. Overall, the study reveals that *Kalanchoe* species in Kenya play a multifaceted and previously underreported role in community health, cultural life, and future economic opportunities through floriculture.

The fourth objective of the study was to assess the current conservation status of the genus *Kalanchoe* in Kenya. The study assessed all 19 native species using IUCN Red List criteria, GeoCAT tool and field observations. The reassessment of conservation statuses revealed that all *Kalanchoe* species in Kenya are significantly threatened with extinction. The findings demonstrated that each species faces significant threats, ranging from habitat loss and climate variability to human encroachment, resulting in classifications from Vulnerable to Critically Endangered. The results emphasize the urgent need for targeted conservation efforts, habitat protection, and regular reassessments to prevent further biodiversity loss within this important genus.

Through the integration of taxonomic, phylogenetic insights, ethnobotanical and conservation study advances critical knowledge essential for the sustainable management and scientific validation of traditional plant uses, in line with WHO recommendations for integrating indigenous knowledge with scientific research.

5.6.2 Recommendations From the Study

i. To delineate species boundaries within the *K. lateritia* and *K. nyikae* species complexes based on molecular and morphometric approaches: The study recommends a revision of *K. lateritia* var. *pseudolateritia* using integrated morphological, ecological, molecular and reproductive data to confirm its proposed status as a distinct variety or subspecies separate from *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata*. Furthermore, there is a need to increase herbarium collections and field sampling of *K. nyikae* and *K. lateritia* to strengthen the understanding of variation within these complexes.

ii. To resolve phylogenetic relationships among the *Kalanchoe* species in Kenya:

Given the success of molecular and morphometric approaches in resolving species complexes, the study recommends supporting advanced molecular research, including DNA barcoding, whole-genome sequencing, and phylogenomic studies.

These approaches will help clarify species boundaries and evolutionary relationships, particularly for outlier species and unresolved taxa (e.g., *Kalanchoe* sp. A and B), and inform conservation and taxonomic decisions.

iii. It is recommended that comprehensive phytochemical analyses and toxicity studies be conducted on *Kalanchoe* species to validate their medicinal properties, determine safe dosage levels, and prevent potential adverse effects associated with misuse. These investigations will support the safe and evidence-based application of *Kalanchoe* in primary healthcare and enhance their pharmacological potential.

iv. It is further recommended that awareness of the ecological, cultural, and economic importance of *Kalanchoe* species be enhanced, and that their horticultural and commercial potential be fully explored within Kenya's ornamental and cut-flower industry. Promoting sustainable cultivation will aid in conservation efforts while contributing to growth in the floriculture sector.

v. To assess the current conservation status of the genus *Kalanchoe* in Kenya:

   Recognizing the threatened status of several *Kalanchoe* species, the study calls for an urgent, comprehensive conservation assessment of all *Kalanchoe* species in Kenya, including those potentially extinct in the wild (e.g., *K. ballyi*). This will help update of the IUCN Red List statuses and the integration of findings into national conservation strategies.Additionally, the study advocates for both *ex-situ* conservation (e.g., seed banks, botanical gardens) and *in-situ* conservation measures, alongside the cultivation of species to relieve pressure on wild populations and support local livelihoods.

5.6.4 Recommendations for Further Work

This study lays the ground for expanded research on the Genus *Kalanchoe* and related succulent taxa. Future research should focus on the following areas:

i. Carry out population level genetic studies in *K. lateritia* and *K. nyikae* and investigate reproductive barriers, hybridization potential, and pollination dynamics among varieties and subspecies.

ii. Investigate the taxonomic variability of species treated as *K. glaucescens, K. crenata and K. prittwitzii* in this study to clarify their close relationship with *K. lateritia* and for identification of new species

iii. Study physiological and genetic traits that support adaptation to diverse Kenyan habitats.

iv. Update IUCN Red List assessments of succulent plants with current field and GeoCAT data.

v. Develop conservation strategies informed by hotspot modeling, climate modeling and species distribution projections. Standardize field collection and seed/specimen preservation protocols; promote *in-situ* and *ex-situ* conservation. Promote environmental education at all levels and implement inclusive, community-based conservation programs.

vi. Document cultural uses of underutilized species (e.g., *K. glaucescens*) and promote awareness of their ecological and therapeutic value.as well as integrate local knowledge, education and policy.

vii. Investigate the use of *Kalanchoe* as sources of biodegradable materials for manure and other ordinally uses by by common farmers.

5.6.5 Taxonomic Revision

i. Recognize *K. lateritia* var. *lateritia* and *K. lateritia* var. *prostrata* as a single variety/subspecies and *K. lateritia* var. *pseudolateritia* as a distinct second variety/subspecies.

ii. Retain *K. nyikae* subsp. *auriculata* as a valid subspecies (not a hybrid), in line with morphometric and molecular findings.

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APPENDICES

Appendix 1: Table Showing Conservation Status of Selected *Kalanchoe* Species Following Red-Listed *Kalanchoe* Species in IUCN (2025).

Species	Distribution	Conservation Status	Year of Assessment	Year of Publication	Notes/Annotation
K. ballyi	Kenya	Endangered (EN)	2009	2022	Needs updating, facing significant threats to survival
K. beharensis	Madagascar	Vulnerable (VU)	2018	2019	Threatened by habitat loss
K. daigremontiana	Madagascar	Endangered (EN)	2016	2017	Endemic to Madagascar, faces significant threats
K. densiflora	Congo, Ethiopia, Kenya, Tanzania, Uganda	Least Concern (LC)	2018	2022	Stable population
K. elizae	Malawi, Mozambique	Least Concern (LC)	2018	2019	Found in Malawi and Mozambique; stable population
K. fadeniorum	Kenya	Extinct in the Wild (EW)	2009	2022	Needs updating, no longer found in its natural habitat
K. farinacea	Arabian Peninsula (Socotra)	Least Concern (LC)	2004	2004	Needs updating, endemic to Socotra; grows on limestone plains
K. fernandesii	Mozambique	Data Deficient (DD)	2020	2020	-
K. hametiorum	Mozambique	Least Concern (LC)	2019	2019	-
K. integrifolia	Madagascar	Vulnerable (VU)	2017	2019	-
K. lateritia	Congo, Kenya, Malawi, Mozambique, Rwanda,	Least Concern (LC)	2007	2020	Needs updating, conservation status

	Tanzania, Zaire, Zimbabwe				
K. nyikae	Kenya, Tanzania	Least Concern (LC)	2009	2022	Needs updating, some conservation concerns exist (Near Threatened)
K. obtusa	Kenya, Tanzania	Vulnerable (VU)	2009	2022	Needs updating, faces habitat threats
K. peteri	Tanzania	Endangered (EN)	2009	2022	Needs updating
K. robusta	Arabian Peninsula – Socotra	Vulnerable (VU)	2004	2004	Needs updating, limited range; declining population
K. usambarensis	Tanzania	Endangered (EN)	2009	2022	Needs updating
K. cherukondensis	India	Critically Endangered (CR)	Unknown	Unknown	Highly threatened due to limited distribution

Appendix 2: Ethnobotanical Survey and Conservation Questionnaire for *Kalanchoe*

Date

Gender

Background information:

1. What is the name of this village, location and county?
2. What is your name? Name: Mr/Mrs/Ms/Prof./Dr./Rev./Ps.:
3. How old are you? 18-25 25-40 41-60 Above 60
4. Highest level of education? Education: Primary Secondary Tertiary Informal None
5. Which address/phone number do you use?
6. What is your occupation? Teacher Doctor Nurse Engineer Farmer Bussinessman Herbalist Others (specify)
7. For how long have you practiced this? (If a herbalist)
8. How many patients do you get in a day?
9. Do you belong to any society?

10. Do some of your patients fail to recover?

Ethnobotany and Conservation data

1. What is the name of the plant? Local: Scientific:
2. How do you recognize the plant? Characters: Morphological Ecological
3. How do you recognize them?
4. Who collects it?
5. How do you use it? Use: Ornamental Medicine Firewood Food Veterinary Others (specify)
6. Which part do you use? Part used: Leaves Back Roots Fruits Seeds Others (Specify)

   If medicinal Human/Veterinary
7. What condition does it treat?
8. How is it prepared? Crushing Powder Decoction Infusion (hot/cold) Ointment Syrup Alcohol extract
9. How is it preserved? In containers Fresh Dry Underground In alcohol Liquid Powder Others

   Oral Inhalation External (specify)

10. How are they administered?

11. How do you treat and monitor patients/animals using the products from this plant? Once a day | Twice a day | Thrice a day

12. How do you harvest the plant?

13. How much is harvested?

14. What is the frequency of harvesting of the product? Year-round | At certain times only

15. Where do you get the plants?

16. Were these plants available before? More | Less | Same

17. When did it happen (If less)

18. Are the plants cultivated?

19. Do you cultivate them on the farm?

20. Are the plants traded? Yes | No

21. Are there any measures that are being taken for the impact of harvesting of the plant resource? Yes | No

Appendix 3: Uses of *Kalanchoe* in Kenya

***Kalanchoe* species**	**Local name and language**	**Plant part used**	**Preparation**	**Condition treated**	**Perceived threats**	Cultivated or wild harvested
K. ballyi Rahm-Hamet ex Cufod.				Unknown	Its growth depends on availability of rainfall	Wild
K. crenata (Andrews) Haw.	*Namafumo* (Luhya-Bukusu) *Rineke* (Luhya-Maragoli)	Leaves Leaves and roots	Burn leaf on hot charcoal then massage the swollen part Crush leaves/roots and apply extract on the affected part Done until the patient recovers Thrice a day	Sprained/swollen leg/hand Antiseptic properties-making soap (herbal) Skin infections, rashes Ringworms Wounds e.g. culturally for circumcision wounds Hernia Blood/immune system/body cleanser Stomachache Ornamental Antimicrobial-Poultry (Veterinary) Aesthetic value- smearing houses	Traditional practices/ herbal medicine is not appreciated by many people especially modern/new spirituality Christians and youth Herbalists are giving up because of the restriction on application for a permit for collection of medicinal plants Road Construction e.g Kolol-Toror Deforestation for farming and construction *K. crenata* is termed as male and believed to be poisonous by some people in western Kenya	Mainly wild; Grow in forests or near homesteads; a few people have planted one or two plants on their farms

K. citrina Schweinf.				Stomachache Antimicrobial (Veterinary (Poultry))	Grows in rocky areas	Wild
K. densiflora Rolfe	*Taragwet*/ *Kuseruwet*/*Morongoch*/ /*Safinacheruiyat* (Kalenjin) *Omoneke* (Kisii) *Mugauta*/*Muhuithia*/*Mukondori* (Kikuyu) *Masilgi* (Maasai) *Mrizongo* (Taita) *Okwa matsi* (Luhya-Idaho/Isukha)	Leaves	Chew the leaves and/or upper part of stem Warm on charcoal and press and put two drops of the extract in the affected ear Heat the leaves in water until the water boils then take the solution obtained Crush the leaves, mix with oil and massage the affected part Rub the affected part with pound/crushed leaves Crush the leaves to obtain the extract Heat leaves on burning charcoal and use them to massage the	Stomachache, upset Diarrhoea Toothache/dental problems Earache Swollen stomach, body, spleen Umbilical hernia Pain reliever/killer e.g. Insect sting or bite swelling and pain Veterinary medicine (antibiotic) especially for poultry Swollen lymph nodes Intestinal worms Ornamental Skin rashes Antiseptic, Anti-inflammatory properties Cough, cold Rheumatism Swollen/sprained leg/hand Musk-circumcision Shed Fuel Food Anal hygiene	Cultivation of forested land Use of herbicides especially in tea plantations kills the plants Increase in population increases the demand for more land for agriculture They grow naturally in farms and can be uprooted for farming Overexploitation Young generation lacks knowledge on the value of the plants Affected by prolonged dry season/ rising temperature	Wild

			affected part Heat a mixture of the leaves, unripe bananas and water until the water boils and take 10-15 ml of the concoction twice a day for three days Planted in home gardens 1-3 times daily			
K.glaucescens Britten	*Masilik* (Maasai)	Leaves	Grows near homesteads	Ornamental	Its growth depends on availability of rainfall	Wild
K. lanceolata (Forssk.) Pers.	*Kipchobos* (Kalenjin) *Masilik ndulelei* (Maasai) *Inyoeni* (Kamba) *Masabo* (Kamba)	Leaves	Warm leaf on burning charcoal then massage the affected part Grows near homesteads Grows widely during rainy season	Arthritis Ornamental Swollen/sprained leg or hand Skin rashes Antiseptic	They grow naturally in farms (weed) and can be uprooted for farming Land degradation Growth depends on availability of rainfall (Dry up during rainy season) Reduced due to changing climatic conditions becoming dryer/higher temperatures/prolonged drought	Wild
K. laciniata (L) DC.				Unknown	Grows on roadsides	Wild

K. lateritia Engl.	*Tangaratwet*/*Buserwet* (Kalenjin) *Mburizongo* (Taita) *Gonzi-chireka*/*Muchira-wa-gonzi* (Duruma)	Leaves	Chew fresh leaves or crush and take the extract Once or twice daily Heat leaves on burning charcoal till warm then press them on the affected part continuously Leaves are mixed with other vegetables	Stomachache Veterinary medicine for poultry Antimicrobial, Antifungal Sprained/ swollen leg or hand Fractured/swollen/sprained leg and hand Swollen spleen Skin rashes, dermatitis infections Antiseptic Chest pain/ache, cough, cold Ornamental Backache Swollen body massage Whistle (leaves) Skin infection Toothache/dental problems	Clearing and fragmentation of forests e.g Chepalungu Grows in rocky areas	Wild
K. marmorata Baker	*Ihuthia* (Kikuyu) *Masilgi* (Maasai)	Leaves	Planted in tree nursery for sale Planted in a pot outside a hotel Massage using warm leaves burnt on hot charcoal	Ornamental (Graveyard, homestead, hospital compound) Sprained leg/hand Wounds Knee ache, rheumatism Swollen body (Traded-pot plant)	Rare due to overexploitation Collected from a different county Its use not known by young herbalists in some places	
K. mitejea Leblanc and Raym.-Hamet				Unknown	Grows on roadsides, near streams and in bushes (beehives located in the bushes)	Wild
K. nyikae				Unknown	Grows at the bed of rocks	Wild

Engl.						
K. obtusa Engl.	*Toro/komba/gonzi-chireku* (Duruma)	Leaves	Pot plant Crush fresh leaves mix with water and take a bath with it Leaves are mixed with other vegetables	Ornamental Fever Food (vegetable) Swollen leg Swollen spleen Pain reliever	Burning of vegetation affects the plant Clearing forests for farming Its growth depends on availability of rainfall New generation does not know the value of the plants	
K. pinnata (Lam.) Pers.				Swollen body parts massage Ornamental	Grows on roadsides	Wild

K. prittwitzii Engl.	*Bebe* (Kalenjin- Pokot) *Namafumo* (Luhya-Bukusu)	Leaves

Appendix 4: Species, Voucher Specimens Deposited at the East African Herbarium (EA), Nairobi and Flora regions That Were Visited During Field Work in Kenya.

Kalanchoe species	Known Distribution	Voucher specimens deposited in EA
K. ballyi Raym.-Hamet ex Cufod.	K7	
K. citrina Schweinf.	K1, 5-6	*Evusa 90*, Baringo (K3), *Evusa 91*, Baringo (K3), *Evusa and Onyango 111*, Narok (K6), *Wabuyele 472*, Machakos (K4),
K. crenata (Andrews) Haw.	K3, 5, 7	*Evusa 4*3 Kakamega (K5), *Evusa 44*, Kakamega (K5), *Evusa 45*, Kakamega (K5), *Evusa 46*, Bungoma (K5), *Evusa 48*, Bungoma (K5), *Evusa 50*, Bungoma (K5), *Evusa 60*, Vihiga (K5), *Evusa 61*, Bungoma (K5), *Evusa 62*, Bungoma (K5), *Evusa 63*, Trans Nzoia (K3), *Evusa 64*, Trans Nzoia (K3), *Evusa 67*, Trans Nzoia (K3), *Evusa 70*, Trans Nzoia (K3), *Evusa 80*, West Pokot (K2),
K. densiflora Rolfe	K1, 5, 6	*Evusa and Tori 39*, Taita Taveta (K7), *Evusa 66*, Trans Nzoia (K3), *Evusa 68*, Trans Nzoia (K3), *Evusa 69*, Trans Nzoia (K3), *Evusa 71*, Trans Nzoia (K3), *Evusa 79*, West Pokot (K2), *Evusa 93A*, Nakuru (K3), *Evusa 94A*, Nyandarua (K4), *Evusa 86*, Nyahururu (K4), *Evusa 96*, Nakuru (K3), *Evusa 97*, Kericho (K3), *Evusa 98*, Kericho (K3), *Evusa 99*, Bomet (K3), *Evusa 101*, Bomet (K3), *Evusa 102*, Bomet (K3), *Evusa 103*, Bomet (K3), *Evusa 104*, Bomet (K3), *Evusa 105*, Bomet (K3), *Evusa 107*, Bomet (K3), *Evusa and Onyango*

		115, Narok (K6), *Evusa and Onyango 131*, Narok (K6), *Wabuyele 480*, Machakos (K4), *Wabuyele 482*, Machakos (K4), *Wabuyele 485*, Machakos (K4), *Wabuyele 491*, Kiambu (K4), *Wabuyele 496*, Naivasha (K4),
K. glaucescens Britten	K2-4, 6, 7	*Evusa and Onyango 116*, Narok (K6), *Evusa and Onyango 117*, Narok (K6), *Evusa and Onyango 125*, Narok (K6), *Evusa and Onyango 128*, Narok (K6), *Evusa and Onyango 130*, Narok (K6), *Evusa and Onyango 135*, Narok (K6), *Wabuyele 474*, Machakos (K4), *Wabuyele 475*, Machakos (K4), *Wabuyele 497*, Naivasha (K4), *Wabuyele 502*, Narok (K4),
K. laciniata (L) DC.	K1, 4-6	*Wabuyele 476*, Machakos (K4), *Wabuyele 478*, Machakos (K4),
K. lanceolata (Forssk.) Pers.	K1-7	*Evusa and Tori.6E*, Machakos (K4); *Evusa and Tori 28*, Machakos (K4), *Evusa and Tori YKR* (Taita Taveta K7), *Evusa and Tori 30*, Taita Taveta (K7), *Evusa and Tori 31*, Taita Taveta (K7), *Evusa and Tori 32*, Taita Taveta (K7), *Evusa 72A*, West Pokot (K2), *Evusa 74A*, West Pokot (K2), *Evusa 77*, West Pokot (K2), *Evusa 81*, Elgeyo Marakwet (K3), *Evusa 87*, Baringo (K3), *Evusa 89*, Baringo (K3), *Evusa and Onyango 108*, Narok (K6), *Evusa and Onyango 109*, Narok (K6), *Evusa and Onyango 110*, Narok (K6), *Evusa and Onyango 123*, Narok (K6), *Evusa and Onyango 134*, Narok (K6), *Wabuyele 479*, Machakos (K4), *Wabuyele 481*, Machakos (K4), *Wabuyele 483*, Machakos (K4), *Wabuyele 484*, Machakos (K4), *Wabuyele 489*, Kiambu (K4), *Wabuyele 494*, Kiambu (K4), *Wabuyele 495*, Naivasha (K4), *Wabuyele 498*, Naivasha (K4),

K. lateritia Engl.	K1, 4-7	*Evusa and Tori B53*, Taita Taveta (K7), *Evusa and Tori 29* (Taita Taveta (K7), *Evusa and Tori 33*, Taita Taveta (K7), *Evusa and Tori 34*, Taita Taveta (K7), *Evusa and Tori 35*, Taita Taveta (K7), *Evusa and Tori 37*, Taita Taveta (K7), *Evusa and Tori 38*, Taita Taveta (K7), *Evusa and Tori 38*, Kwale (K7), *Evusa and Tori 40*, Kwale (K7), *Evusa and Tori 41*, Kwale (K7), *Evusa and Tori 42*, Kwale (K7), *Evusa 55*, Busia (K5), *Evusa 56*, Busia (K5), *Evusa 57*, Busia (K5), *Evusa 58*, Busia (K5), *Evusa 100*, Bomet (K5), *Evusa 106*, Bomet (K3), *Evusa and Onyango 108*, Narok (K6), *Evusa and Onyango 113*, Narok (K6), *Evusa and Onyango 114*, Narok (K6), *Evusa and Onyango 119*, Narok (K6), *Evusa and Onyango 121*, Narok (K6), *Evusa and Onyango 122*, Narok (K6), *Evusa and Onyango 124*, Narok (K6), *Evusa and Onyango 132*, Narok (K6), *Evusa and Onyango 133*, Narok (K6), *Evusa and Onyango 126*, Narok (K6), *Evusa and Onyango 129*, Narok (K6), *A.M, Mwadime, Evusa 013*, Taita Taveta (K7)
K. marmorata Baker	K1, 4, 6	*Evusa and Onyango 118*, Narok (K6), *Evusa and Onyango 120*, Narok (K6),
K. mitejea Leblanc and Raym.-Hamet	K3, 4, 6, 7	*Evusa 88*, Baringo (K3), *Evusa 92*, Baringo (K3),
K. nyikae Engl.	K4, 6, 7	*A.M, Mwadime, Evusa 019*, Taita Taveta (K7)
K. obtusa Engl.	K7	

K. pinnata (Lam.) Pers.	K4, 5	
K. prittwitzii Engl.	K1- 6	*Evusa 47*, Bungoma (K5), *Evusa 49*, Bungoma (K5), *Evusa 51*, Bungoma (K5), *Evusa 52*, Busia (K5), *Evusa 65*, Trans Nzoia (K3), *Evusa 73*, West Pokot (K2), *Evusa 75*, West Pokot (K2), *Evusa 76*, West Pokot (K2), *Evusa 78A*, West Pokot (K2), *Evusa 82A*, Elgeyo Marakwet (K3), *Evusa 83A*, Elgeyo Marakwet (K3), *Evusa 84*, Baringo (K3), *Evusa 85*, Baringo (K3), *Evusa 86*, Baringo (K3), *Wabuyele 465*, Kajiado (K4),

Appendix 5. List of Specimens Examined and Used in Morphological Studies

No.	Name
Adeka and kirika 139	*K. lateritia* var. *lateritia*
Malin J.158	*K. lateritia* var. *lateritia*
Dewevre A. 1074	*K. lateritia* var. *lateritia*
Mr.J.R. Wetch 254	*K. lateritia* var. *lateritia*
Pedeo and Pedrogao 4577	*K. lateritia* var. *lateritia*
Moreau R.E, Moreau W.M 9062	*K. lateritia* var. *lateritia*
W. Rauh T72	*K. lateritia* var. *lateritia*
Mrs. S.A. Robertson 1958	*K. lateritia* var. *lateritia*
Evusa and Tori 29A	*K. lateritia* var. *lateritia*
M.Bigger 1983	*K. lateritia* var. *lateritia*
Burtt B.D 4826	*K. lateritia* var. *lateritia*
Greenway 4054	*K. lateritia* var. *lateritia*
O. Flock 447	*K. lateritia* var. *lateritia*
Evusa and Tori 033a	*K. lateritia* var. *lateritia*
Evusa 55 A	*K. lateritia* var. *lateritia*
Evusa and Tori 0 38 A	*K. lateritia* var. *lateritia*
J.R Wetch 299	*K. lateritia* var. *lateritia*
Dr. W.Busse 2871	*K. lateritia* var. *lateritia*
Colline Kayonza 3238	*K. lateritia* var. *lateritia*
M. Reekmans 2645	*K. lateritia* var. *lateritia*
Gillet J.B 20380	*K. lateritia* var. *lateritia*

Bally P. R. O B9760	*K. lateritia* var. *lateritia*
Napper D. 1608	*K. lateritia* var. *lateritia*
Kirika Paul 240	*K. lateritia* var. *lateritia*
Hanid *et al*. 1133	*K. lateritia* var. *lateritia*
Gilbert 4850	*K. lateritia* var. *lateritia*
Mrs. Robertson 5766	*K. lateritia* var. *lateritia*
Bally P. R. O B6371	*K. lateritia* var. *lateritia*
Evusa G. V. and Onyango D. 122	*K. lateritia* var. *lateritia*
Evusa G. V. and Onyango D. 124	*K. lateritia* var. *lateritia*
Evusa G. V. and Onyango D. 129	*K. lateritia* var. *lateritia*
Evusa G. V. and Onyango D. 126	*K. lateritia* var. *lateritia*
Mrs. J. A Robertson 839	*K. lateritia* var. *lateritia*
Bally P.R.O B 11455	*K. lateritia* var. *pseudolateritia*
Zitiert 1977	*K. lateritia* var. *prostrata*
Luke and Robertson 2269	*K. lateritia* var. *prostrata*
Robertson and Luke 6002	*K. lateritia* var. *prostrata*
Evusa and Tori 041	*K. lateritia* var. *prostrata*
Drummond and Hemsley 3790	*K. lateritia* var. *prostrata*
Evusa V.G 100	*K. lateritia* var. *pseudolateritia*
Greenway P .J 10898	*K. lateritia* var. *pseudolateritia*
Bally B 1253	*K. lateritia* var. *pseudolateritia*
Evusa and Tori 042 a	*K. lateritia* var. *pseudolateritia*
Capilo 316	*K. nyikae* sp. *auriculata*

Gillet J.B 16174	*K. nyikae* sp. *auriculata*
Greenway P.J.10760	*K. nyikae* sp. *auriculata*
Hanid *et al*.1144 M.Afzal Hanid E.Raads	*K. nyikae* sp. *auriculata*
Pfennig 1079/1	*K. nyikae* sp. *auriculata*
Bally P.R.O 1068	*K. nyikae* sp. *auriculata*
Agnew 10209	*K. nyikae* sp. *auriculata*
Bally P.R.O B5429	*K. nyikae* sp. *auriculata*
Kuchar 14412	*K. nyikae* sp. *auriculata*
Hanid *et al*. 1129	*K. nyikae* sp. *auriculata*
Bally B2601	*K. nyikae* sp. *auriculata*
Bigger M 2208	*K. nyikae* sp. n*yikae*
Jeffrey G.W 248 (B7993)	*K. nyikae* sp. *nyikae*
Greenway P.J 6695	*K. nyikae* sp. *nyikae*
Luke and Robertson 2223	*K. nyikae* sp. *nyikae*
Luke and Robertson 2555	*K. nyikae* sp. *nyikae*
Mwachala *et al*. in E W 3215	*K. nyikae* sp. *nyikae*
H.E.K.Hartman and L.E.Newton 28616	*K. nyikae* sp. *nyikae*
Luke and Robertson 2017	*K. nyikae* sp. *nyikae*
Faden, Evans and Githui 70/ 151	*K. nyikae* sp. *nyikae*
Bally B13771	*K. nyikae* sp. *nyikae*

Appendix 6: List of Specimens Observed and Used in Conservation Studies Including Part of the GeOCAT Data

SPECIMEN NO.	SPECIES NAME	COUNTRY NAME	LOCALITY	LATITUDE	NS	LONGITUDE	EW	ALTITUDE	YEAR
5139	***K. ballyi***	Kenya	Kilifi	3.45	S	39.73333	E	85	21/2/1988
6378	***K. ballyi***	Kenya	Kwale	3.966667	S	38.95	E	500	17/11/1989
1673	***K. ballyi***	Kenya	Kilifi	3.666667	S	39.73333	E	150	21/2/1989
1829	***K. ballyi***	Kenya	Kilifi	3.333333	S	39.86667	E	-9999	2/1920
14650	***K. ballyi***	Kenya	Kilifi	3.733333	S	39.7	E	200	21/11/1978
65	***K. ballyi***	Kenya	Kilifi	3.716667	S	39.7	E	200	1/10/1972
1887	***K. ballyi***	Kenya	Kilifi	3.35	S	39.96667	E	-9999	7/1929
450	***K. ballyi***	Kenya	Kilifi	3.616667	S	39.85	E	-9999	28/1/1946
1642	***K. ballyi***	Kenya	Kwale	3.733333	S	39.05	E	-9999	26/11/1985
23991	***K. ballyi***	Kenya	Kwale	4.216667	S	39.5	E	-9999	25/12/1982
7994	***K. ballyi***	Kenya	Kilifi	3.616667	S	39.85	E	-9999	9/1950
1736	***K. bipartita***	Kenya	Embu	0.45	S	37.78333	E	850	18/1/1972
1507	***K. bipartita***	Kenya	Embu	0.45	S	37.78333	E	-9999	28/5/1984
522	***K. bipartita***	Kenya	Kitui	2.353417	S	38.85439	E	556	21/1/2005
14892	***K. bipartita***	Kenya	Marsabit	3.516667	N	39.05	E	930	18/1/1972
9107	***K. bipartita***	Kenya	Marsabit	3.516667	N	39.05	E	1448	3/9/1953
356	***K. citrina***	Kenya	Samburu	2.05	N	36.85	E	1600	1/4/1995
340	***K. citrina***	Kenya	Samburu	2.05	N	36.85	E	1600	1/4/1995
14558	***K. citrina***	Kenya	Marsabit	2.616667	N	36.91667	E	1575	29/1/1981
5360	***K. citrina***	Kenya	Samburu	0.866667	N	37.56667	E	1600	15/4/1979
5482	***K. citrina***	Kenya	Samburu	1.833333	N	36.81667	E	1350	3/6/1979
5550	***K. citrina***	Kenya	Marsabit	1.716667	N	37.25	E	1350	8/6/1979
21810	***K. citrina***	Kenya	Samburu	0.9	N	37.55	E	1350	15/4/1979

54	***K. citrina***	Kenya	Samburu	0.833333	N	37.53333	E	1829	5/2/1969
69	***K. citrina***	Kenya	Marsabit	2.716667	N	36.91667	E	-9999	8/6/1960
68/645	***K. citrina***	Kenya	Marsabit	2.4	N	37.9	E	1524	14/8/1968
46	***K. citrina***	Kenya	Samburu	1.316667	N	36.78333	E	1280	2/2/1983
21831	***K. citrina***	Kenya	Baringo	0.283333	N	35.9	E	1440	27/4/1979
523	***K. citrina***	Kenya	Samburu	1.816667	N	36.98333	E	1875	18/11/1977
197	***K. citrina***	Kenya	Marsabit	2.616667	N	36.91667	E	1676	23/1/1977
14885	***K. citrina***	Kenya	Marsabit	3.55	N	38.63333	E	950	17/1/1972
641	***K. citrina***	Kenya	Marsabit	3.5	N	37.85	E	1524	7/1957
15123	***K. citrina***	Kenya	Marsabit	2.316667	N	37.98333	E	1300	16/2/1953
310	***K. citrina***	Kenya	Marsabit	1.8	N	37.38333	E	1219	6/8/1978
3605	***K. citrina***	Kenya	Samburu	1.266667	N	37.28333	E	1829	25/4/1944
132	***K. citrina***	Kenya	Nakuru	0.416667	S	36.08333	E	1829	7/8/1967
13891	***K. citrina***	Kenya	Nakuru	0.033333	S	36.2	E	1700	21/6/1975
503	***K. citrina***	Kenya	Nakuru	0.533333	S	36.31667	E	2000	14/6/1977
8387	***K. citrina***	Kenya	Machakos/Kitui	2	S	38	E	1158	7/12/1952
1869	***K. citrina***	Kenya	Kitui	0.816667	S	38.1	E	853	22/4/1973
1337	***K. citrina***	Kenya	Kiambu	1.2	S	37.06667	E	-9999	14/9/1977
1052	***K. citrina***	Kenya	Thika	1.05	S	37.08333	E	-9999	3/1972
698	***K. citrina***	Kenya	Muranga	0.766667	S	37.2	E	-9999	3/9/1972
1662	***K. citrina***	Kenya	Kitui	1.183333	S	38	E	-9999	8/5/1960
70/134	***K. citrina***	Kenya	Machakos	1.083333	S	37.43333	E	1480	24/5/1970
2	***K. citrina***	Kenya	Nairobi	1.283333	S	36.81667	E	1676	29/8/1975
9766	***K. citrina***	Kenya	Machakos	1.183333	S	37.55	E	1189	9/6/1954
1740	***K. citrina***	Kenya	Laikipia	0.216667	N	36.96667	E	1700	15/12/1984

1510	***K. citrina***	Kenya	Machakos/Kitui	2	S	38	E	-9999	17/1/1942
s.n.	***K. citrina***	Kenya	South Nyanza	0.383333	S	34.5	E	-9999	12/1934
1062	***K. citrina***	Kenya	Kajiado	1.5	S	36.55	E	1900	1/6/1977
625	***K. citrina***	Kenya	Narok	1.716667	S	35.35	E	1975	2/6/1979
2086	***K. citrina***	Kenya	Samburu	2.166667	N	36.83333	E	2134	24/7/1960
24	***K. citrina***	Kenya	Samburu	1.05	N	36.7	E	1895	31/7/2006
2769	***K. citrina***	Ethiopia	Harerge	9.316667	N	40.76361	E	1440	20/10/1972
10841	***K. citrina***	Kenya	Marsabit	2.766667	N	36.91667	E	2000	0
14295	***K. citrina***	Kenya	Samburu	1.2633	N	37.2525	E	2000	12/6/2010
2844	***K. citrina***	Kenya	Kajiado	2.55	S	37.71667	E	1100	9/6/1991
18976	***K. crenata***	Kenya	Nakuru	1.016667	S	36.48333	E	-9999	22/11/1992
383	***K. crenata***	Kenya	Bungoma	0		0		1981	0
164	***K. crenata***	Kenya	Bungoma	0		0		2134	12/1931
279	***K. crenata***	Kenya	Trans Nzoia	0		0		1920	31/1/1958
644	***K. crenata***	Kenya	Uasin Gishu/Nandi	0		0		1676	12/1931
637	***K. crenata***	Kenya	Trans Nzoia	1.033333	N	35	E	-9999	20/2/1960
39	***K. crenata***	Kenya	Trans Nzoia	1.033333	N	35	E	-9999	8/10/1968
1072	***K. crenata***	Kenya	Kericho	0.633333	S	35.2	E	-9999	3/1972
23	***K. densiflora***	Kenya	Samburu	1.05	N	36.7	E	1895	31/7/2006
653	***K. densiflora***	Kenya	Trans Nzoia	1.25	N	35.45	E	-9999	2/1960
4824	***K. densiflora***	Kenya	Nakuru	0.166667	S	35.68333	E	2225	1/1946
2637	***K. densiflora***	Kenya	Samburu	1.75	N	37.13333	E	1829	9/12/1960
3769	***K. densiflora***	Kenya	Marsabit	2.333333	N	37.98333	E	1524	21/5/1962
364	***K. densiflora***	Kenya	Marsabit	2.333333	N	37.98333	E	-9999	20/8/1959
18093	***K. densiflora***	Kenya	Samburu	1.666667	N	36.86667	E	2250	26/3/1967

384	***K. densiflora***	Kenya	Samburu	0		0		2500	18/12/1976
85	***K. densiflora***	Kenya	West Pokot	1.216667	N	35.4	E	2870	5/8/1968
7231	***K. densiflora***	Kenya	Turkana	3.166667	N	35	E	2134	17/2/1965
2074	***K. densiflora***	Kenya	Nakuru	0.716667	S	36.43333	E	1890	6/12/1981
12	***K. densiflora***	Kenya	Nakuru	0.416667	S	36.08333	E	1768	29/11/1970
6	***K. densiflora***	Kenya	Elgeyo Marakwet	0		0		2286	7/1957
439	***K. densiflora***	Kenya	Trans Nzoia	1.15	N	34.76667	E	2591	25/12/1967
3270	***K. densiflora***	Kenya	<several>	0.416667	S	36.7	E	3048	2/1/1973
154	***K. densiflora***	Kenya	Nakuru	0.766667	S	36.4	E	1890	22/10/1976
11749	***K. densiflora***	Kenya	Kericho	0.233333	S	35.6	E	-9999	26/11/1971
9532	***K. densiflora***	Kenya	Nyandarua	0.7	S	36.55	E	2600	20/8/1978
6495	***K. densiflora***	Kenya	Bungoma	1.05	N	34.75	E	2350	8/2/1979
2095	***K. densiflora***	Kenya	Nakuru	0.416667	S	36.08333	E	-9999	22/10/1967
3922	***K. densiflora***	Kenya	Nakuru	0.533333	S	36.25	E	228	17/1/1963
653	***K. densiflora***	Kenya	West Pokot	1.25	N	35.45	E	-9999	20/2/1960
38	***K. densiflora***	Kenya	Trans Nzoia	1.033333	N	35	E	-9999	8/10/1968
11441	***K. densiflora***	Kenya	Kiambu	1.133333	S	36.56667	E	-9999	5/4/1957
4824	***K. densiflora***	Kenya	Nakuru	0		0		2225	15/1/1946
9042	***K. densiflora***	Kenya	Kericho	0.15	S	35.6	E	-9999	14/11/1967
1631	***K. densiflora***	Kenya	Nyandarua	0.066667	S	36.36667	E	1829	2/1/1932
87	***K. densiflora***	Kenya	Uasin Gishu	0		0		2195	12/1931
661	***K. densiflora***	Kenya	Kericho	0.166667	S	35.6	E	1829	12/1931
1394	***K. densiflora***	Kenya	Nyandarua	0.683333	S	36.66667	E	2591	22/11/1959
77	***K. densiflora***	Kenya	Kajiado	1.416667	S	36.63333	E	2225	9/7/1939
1628	***K. densiflora***	Kenya	Nakuru	0.716667	S	36.43333	E	1829	26/12/1931

246	***K. densiflora***	Kenya	Bungoma	0		0		2042	13/11/1957
752	***K. densiflora***	Kenya	Nakuru	0.75	S	36.35	E	1890	13/10/1990
23	***K. densiflora***	Kenya	Nakuru	0.45	S	36.13333	E	-9999	2/1960
8723	***K. densiflora***	Kenya	Trans Nzoia	1.033333	N	35	E	1951	6/1942
398	***K. densiflora***	Kenya	Bungoma	0		0		2134	1/1933
909	***K. densiflora***	Kenya	Unknown	0		0		-9999	27/1/1983
5	***K. densiflora***	Kenya	Unknown	0		0		1900	28/6/1984
2783	***K. densiflora***	Kenya	Laikipia	0.083333	N	37.25	E	2250	15/2/1986
16563	***K. densiflora***	Kenya		0.01	N	36.54	E	1750	26/12/1964
31	***K. densiflora***	Kenya	Machakos	1.116667	S	37.25	E	-9999	4/7/1982
7770	***K. densiflora***	Kenya	Kiambu	1.25	S	36.71667	E	1700	6/11/1977
s.n.	***K. densiflora***	Kenya	Unknown	0		0		-9999	0
74/668	***K. densiflora***	Kenya	Nyeri	0.4	S	36.98333	E	1650	1/6/1974
7606	***K. densiflora***	Kenya	Kiambu	1.116667	S	36.65	E	-9999	25/12/1965
7661	***K. densiflora***	Kenya	Kajiado	1.416667	S	36.63333	E	-9999	9/1/1966
119	***K. densiflora***	Kenya	Narok	1.7	S	35.83333	E	2134	4/11/1975
1128	***K. densiflora***	Kenya	Narok	1.083333	S	35.86667	E	-9999	18/8/1973
1132	***K. densiflora***	Kenya	Narok	1.15	S	35.76667	E	-9999	18/8/1973
1137	***K. densiflora***	Kenya	Narok	1.25	S	35.58333	E	-9999	19/8/1973
14528	***K. densiflora***	Kenya	Narok	1.7	S	35.81667	E	2300	21/1/1981
14293	***K. densiflora***	Kenya	Narok	0		0		2425	18/1/1981
16141	***K. densiflora***	Kenya	Kajiado	1.416667	S	36.63333	E	2300	16/8/1964
5502	***K. densiflora***	Kenya	Narok	1.233333	S	34.8	E	1675	5/12/1976
5243	***K. densiflora***	Kenya	Narok	1.016667	S	35.5	E	1975	7/10/1976
8415	***K. densiflora***	Kenya	Machakos	1.916667	S	37.55	E	1829	18/6/1966

1279	***K. densiflora***	Kenya	Narok	1.083333	S	35.86667	E	2317	17/5/1961
24	***K. densiflora***	Kenya	Nakuru	0.683333	S	35.95	E	2804	2/3/1962
1143	***K. densiflora***	Kenya	Narok	1.083333	S	35.86667	E	-9999	19/8/1973
8035	***K. densiflora***	Kenya	Nairobi	1.25	S	36.83333	E	1638	18/11/1966
19380	***K. densiflora***	Kenya	Machakos	1.433333	S	37.2	E	1900	13/12/1971
16835	***K. densiflora***	Kenya	Nyeri	0.083333	N	37.16667	E	2000	9/8/1965
1165	***K. densiflora***	Kenya	Nairobi	1.283333	S	36.81667	E	1798	1930
3006	***K. densiflora***	Kenya	Kiambu	0.866667	S	36.71667	E	-9999	11/2/1972
428	***K. densiflora***	Kenya	Unknown	0		0		-9999	3/1940
2007	***K. densiflora***	Kenya	Kirinyaga	0.366667	S	37.31667	E	2440	2/3/1974
2584	***K. densiflora***	Kenya	Nyeri	0.416667	S	36.95	E	1829	18/1/1933
2329	***K. densiflora***	Kenya	Nairobi	1.283333	S	36.81667	E	1737	11/1932
799	***K. densiflora***	Kenya	Nairobi	1.283333	S	36.81667	E	1798	20/2/1930
17	***K. densiflora***	Kenya	Laikipia	0.016667	N	37.06667	E	2073	18/6/1943
25	***K. densiflora***	Kenya	Kiambu	1.116667	S	36.65	E	-9999	6/1960
747	***K. densiflora***	Kenya	Nairobi	1.266667	S	36.78333	E	1646	2/1940
52	***K. densiflora***	Kenya	Kirinyaga	0.3	S	37.31667	E	2088	6/1/1967
442	***K. densiflora***	Kenya	Nairobi	1.283333	S	36.81667	E	1707	0
8399	***K. densiflora***	Kenya	Kirinyaga	0.366667	S	37.3	E	2073	5/1/1967
1021	***K. densiflora***	Kenya	Machakos/Kajiado	2.566667	S	37.83333	E	1676	14/6/1938
27232	***K. densiflora***	Tanzania	Arusha	3.25	S	36.75	E	-9999	18/9/1971
14406	***K. densiflora***	Kenya	Narok	1.7	S	35.81667	E	2525	21/1/1981
14238	***K. densiflora***	Kenya	Narok	0		0		2300	18/1/1981
1142	***K. densiflora***	Kenya	Narok	1.083333	S	35.86667	E	-9999	19/8/1973
1447	***K. densiflora***	Kenya	Narok	0.783333	S	35.93333	E	2896	22/5/1961

1013	***K. densiflora***	Kenya	Narok	0.633333	S	35.85	E	2926	14/5/1961
777	***K. densiflora***	Kenya	Narok	1.4	S	35.21667	E	2103	28/4/1961
77	***K. densiflora***	Kenya	Kajiado	1.416667	S	36.63333	E	2225	9/7/1939
3094	***K. densiflora***	Kenya	Narok	1.216667	S	35.4	E	1829	15/9/1949
13836	***K. densiflora***	Kenya	Narok	0		0		2652	12/10/1969
1502	***K. densiflora***	Kenya	Narok	0		0		2439	22/5/1961
992	***K. densiflora***	Kenya	Narok	0.633333	S	35.85	E	2682	13/5/1961
230	***K. densiflora***	Kenya	Narok	0		0		1981	30/3/1961
1717	***K. densiflora***	Kenya	Narok	0.933333	S	35.66667	E	2134	6/6/1961
776	***K. densiflora***	Kenya	Narok	1.4	S	35.21667	E	2103	28/4/1961
97	***K. densiflora***	Kenya	Narok	1.216667	S	35.03333	E	1829	4/10/1956
6	***K. densiflora***	Kenya	Taita Taveta	3.583333	S	38.5	E	-9999	0
495	***K. densiflora***	Kenya	Taita Taveta	3.366667	S	38.33333	E	1800	5/5/1985
314	***K. densiflora***	Kenya	Kajiado	1.416667	S	36.63333	E	-9999	7/12/1984
220	***K. densiflora***	Kenya	Samburu	2.116667	N	36.83333	E	2500	30/3/1995
2087	***K. densiflora***	Kenya	Samburu	2.166667	N	36.83333	E	2743	25/7/1960
s.n.	***K. densiflora***	Kenya	Makueni	1.716667	S	37.41667	E	-9999	19/6/1997
s.n.	***K. densiflora***	Kenya	Unknown	0		0		-9999	0
s.n.	***K. densiflora***	Kenya	Makueni	1.716667	S	37.41667	E	-9999	0
357	***K. densiflora***	Kenya	Nandi	0		0		-9999	8/12/1985
220	***K. densiflora***	Kenya	Samburu	2.116667	N	36.83333	E	762	30/3/1995
199	***K. densiflora***	Kenya	Nakuru	0.416667	S	36.08333	E	-9999	19/11/1990
494	***K. densiflora***	Kenya	Trans Nzoia	0		0		1900	19/12/1985
1901	***K. densiflora***	Kenya	Nyandarua	0.716667	S	36.66667	E	2400	19/11/2000
641	***K. densiflora***	Kenya	Taita Taveta	0		0		1750	7/7/2000

1280	***K. densiflora***	Kenya	Taita Taveta	3.316667	S	38.45	E	1700	19/2/1999
236	***K. densiflora***	Kenya	Taita Taveta	0		0		1450	27/5/2000
s.n.	***K. densiflora***	Kenya	Unknown	0		0		-9999	0
s.n.	***K. densiflora***	Kenya	Makueni	1.716667	S	37.41667	E	-9999	0
1625	***K. densiflora***	Kenya	Kisumu	0.183333	S	35.3	E	-9999	8/12/1956
4159	***K. densiflora***	Kenya	Kajiado	2.466667	S	36.76667	E	2286	8/12/1944
4	***K. densiflora***	Kenya	Nandi	0.133333	N	35.33333	E	2134	12/1951
488	***K. densiflora***	Kenya	Nakuru	0.716667	S	36.43333	E	2700	13/2/1960
60	***K. densiflora***	Kenya	Nakuru	0		0		2439	8/11/1959
12294	***K. densiflora***	Kenya	Kajiado	1.8	S	36.03333	E	-9999	1/1961
1499	***K. densiflora***	Kenya	Narok	0		0		2439	22/5/1961
1138	***K. densiflora***	Kenya	Narok	1.25	S	35.58333	E	-9999	19/8/1973
1654	***K. densiflora***	Kenya	Narok	0.933333	S	35.66667	E	2134	6/6/1954
488	***K. densiflora***	Kenya	Rift valley	0.716667	S	36.43333	E	-9999	13/2/1960
1132	***K. densiflora*** x ***lanceolata***	Kenya	Narok	1.15	S	35.76667	E	-9999	18/8/1973
77/777	***K. fadeniorum***	Kenya	Kwale	3.733333	S	39.05	E	360	11/3/1977
77/777	***K. fadeniorum***	Kenya	Kwale	4.05	S	39.66667	E	360	11/3/1977
40	***K. germanae***	Kenya	Kajiado	0		0		1219	28/3/1948
653	***K. glaucescens***	Kenya	Bomet	0.933333	S	35.28333	E	1036	28/11/1960
2059	***K. glaucescens***	Kenya	West Suk	1.483333	N	35.5	E	609	5/1932
3592	***K. glaucescens***	Kenya	Nakuru	0.916667	S	36.43333	E	1951	14/1/1962
4029	***K. glaucescens***	Kenya	Nakuru	0.916667	S	36.43333	E	1981	16/8/1962
3568	***K. glaucescens***	Kenya	Nakuru	0.916667	S	36.43333	E	1890	14/1/1962
150	***K. glaucescens***	Kenya	Nakuru	0		0		1981	20/8/1972
16176	***K. glaucescens***	Kenya	Nakuru	0.933333	S	36.31667	E	1800	13/9/1964

17324	***K. glaucescens***	Kenya	Kiambu	1.2	S	37.5	E	1440	17/7/1966
67/637	***K. glaucescens***	Kenya	Thika	1.05	S	37.08333	E	-9999	16/8/1967
8485	***K. glaucescens***	Kenya	Kiambu	1.2	S	37.06667	E	-9999	18/7/1966
68/180	***K. glaucescens***	Kenya	Thika	1.05	S	37.08333	E	1524	28/4/1968
10	***K. glaucescens***	Kenya	Machakos	0		0		1550	0
20748	***K. glaucescens***	Kenya	Machakos	1.433333	S	37.2	E	1830	21/10/1974
4888	***K. glaucescens***	Kenya	Machakos	0		0		1600	17/6/1976
23	***K. glaucescens***	Kenya	Nairobi	1.266667	S	36.83333	E	1650	18/9/1974
1964	***K. glaucescens***	Kenya	Nairobi	1.283333	S	36.81667	E	1550	19/2/1972
33	***K. glaucescens***	Kenya	Kiambu	1.133333	S	36.91667	E	-9999	5/10/1968
1207	***K. glaucescens***	Kenya	Machakos/Kajiado	2.566667	S	37.83333	E	1676	6/1938
11904	***K. glaucescens***	Kenya	Machakos	1.483333	S	37.06667	E	1524	1937
376	***K. glaucescens***	Kenya	Machakos/Kajiado	2.566667	S	37.83333	E	1524	6/1938
s.n.	***K. glaucescens***	Kenya	Nairobi	1.283333	S	36.81667	E	1737	6/8/1943
222	***K. glaucescens***	Kenya	Kiambu	1.116667	S	36.98333	E	-9999	19/7/1952
67/735	***K. glaucescens***	Kenya	Thika	1.05	S	37.08333	E	1524	10/9/1967
3471	***K. glaucescens***	Kenya	Nairobi	1.283333	S	36.81667	E	1737	7/1934
815	***K. glaucescens***	Kenya	Nairobi	1.35	S	36.75	E	1829	15/3/1931
341	***K. glaucescens***	Kenya	Nairobi	1.283333	S	36.81667	E	1798	7/1930
3470	***K. glaucescens***	Kenya	Nairobi	1.283333	S	36.81667	E	1737	7/1934
457	***K. glaucescens***	Kenya	Kisii	0		0		2100	6/1/1975
425	***K. glaucescens***	Kenya	Narok	1.4	S	34.78333	E	1800	20/7/1978
5133	***K. glaucescens***	Kenya	Narok	1.6	S	35.63333	E	2100	27/8/1976
1130	***K. glaucescens***	Kenya	Narok	1.083333	S	35.86667	E	-9999	18/8/1973
1132	***K. glaucescens***	Kenya	Narok	1.15	S	35.76667	E	-9999	18/8/1973

1140	***K. glaucescens***	Kenya	Narok	1.25	S	35.58333	E	-9999	19/8/1973
1136	***K. glaucescens***	Kenya	Narok	1.25	S	35.58333	E	-9999	19/8/1973
1087	***K. glaucescens***	Kenya	Kajiado	1.85	S	36.78333	E	-9999	5/4/1973
1077	***K. glaucescens***	Kenya	Narok	1.15	S	35.76667	E	-9999	5/6/1972
1071	***K. glaucescens***	Kenya	Kericho	0.633333	S	35.2	E	-9999	30/3/1972
813	***K. glaucescens***	Kenya	Narok	1.4	S	35.21667	E	2103	28/4/1961
2630	***K. glaucescens***	Kenya	Narok	0		0		2103	8/10/1961
106	***K. glaucescens***	Kenya	Narok	0.333333	S	35	E	1676	5/10/1956
2337	***K. glaucescens***	Kenya	Kajiado	1.85	S	36.78333	E	1753	11/1932
77/579	***K. glaucescens***	Kenya	Kwale	3.816667	S	39.33333	E	210	22/2/1977
508	***K. glaucescens***	Kenya	Kilifi	0		0		-9999	12/1980
6353	***K. glaucescens***	Kenya	Kilifi	3.416667	S	39.8	E	15	26/1/1979
13420	***K. glaucescens***	Kenya	Taita Taveta	3.366667	S	38.13333	E	1100	17/8/1969
1967	***K. glaucescens***	Kenya	Machakos	2.466667	S	37.76667	E	1400	28/10/1989
248	***K. hemsleyana***	Kenya	Kilifi	3.466667	S	39.3	E	304	3/7/1945
9898	***K. laciniata***	Kenya	Marsabit	0		0		1981	10/10/1947
6583	***K. laciniata***	Kenya	Marsabit	0		0		1829	10/1947
925	***K. laciniata***	Kenya	Narok	1.183333	S	36.25	E	1524	4/12/1976
22706	***K. laciniata***	Kenya	Nakuru	0.416667	S	36.08333	E	-9999	15/8/1979
5008	***K. laciniata***	Kenya	Machakos	2.083333	S	37.48333	E	1524	7/1940
2350	***K. laciniata***	Kenya	Machakos	1.483333	S	37.06667	E	1737	1/12/1932
302	***K. laciniata***	Kenya	Bungoma	0.833333	N	34.95	E	2000	28/11/1984
1089	***K. laciniata***	Kenya	Kajiado	1.85	S	36.78333	E	-9999	5/4/1973
2995	***K. laciniata***	Kenya	Kajiado	1.416667	S	36.63333	E	1829	1938
7447	***K. laciniata***	Kenya	Kajiado	1.416667	S	36.63333	E	-9999	1/1938

988	***K. laciniata***	Kenya	Narok	1.083333	S	35.86667	E	-9999	7/1957
10602	***K. laciniata***	Kenya	Kajiado	1.85	S	36.78333	E	1737	30/6/1956
2924	***K. laciniata***	Kenya	Kajiado	1.55	S	36.56667	E	1349	30/6/1962
3575	***K. laciniata***	Kenya	Narok	1.183333	S	36.25	E	1890	3/4/1963
3910	***K. laciniata***	Kenya	Narok	1.183333	S	36.25	E	1585	31/8/1963
2111	***K. laciniata***	Kenya	Kajiado	0		0		2134	7/1932
125	***K. laciniata***	Kenya	Unknown	1.566667	S	36.05	E	1463	20/7/1976
124	***K. laciniata***	Kenya	Unknown	1.566667	S	36.05	E	1463	20/7/1976
21547	***K. laciniata***	Kenya	Kajiado	2.516667	S	36.85	E	1750	17/9/1977
186	***K. laciniata***	Kenya	Unknown	0		0		-9999	20/6/1988
196	***K. laciniata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	27/4/1977
14883	***K. laciniata***	Kenya	Marsabit	3.55	N	38.63333	E	-9999	1/1972
214	***K. laciniata***	Kenya	Riftvalley	2.56	S	36.41	E	1524	22/5/1992
13519	***K. laciniata***	Kenya	Marsabit	3.533333	N	39.05	E	1080	7/7/1952
2587	***K. laciniata***	Kenya	Samburu	1.266667	N	37.28333	E	2134	7/12/1960
32	***K. laciniata***	Kenya	Samburu	0.983333	N	37.33333	E	1280	26/1/1969
658	***K. laciniata***	Kenya	Samburu	1.266667	N	37.28333	E	1524	8/7/1977
17006	***K. laciniata***	Kenya	Isiolo	0.35	N	37.58333	E	-9999	7/6/1984
12719	***K. laciniata***	Kenya	Mandera	3.433333	N	39.9	E	750	7/4/1952
20	***K. laciniata***	Kenya	Turkana	4.266667	N	35.76667	E	-9999	12/1981
93	***K. laciniata***	Kenya	Turkana	0		0		853	10/12/1978
240	***K. laciniata***	Kenya	Nakuru	0.766667	S	36.4	E	1890	31/7/1977
6407	***K. laciniata***	Kenya	Narok	1.6	S	35.25	E	1750	29/5/1977
1597	***K. laciniata***	Kenya	Baringo	0.966667	N	35.95	E	-9999	28/12/1977
21831	***K. laciniata***	Kenya	Baringo	0.283333	N	35.9	E	1440	27/4/1979

43	***K. laciniata***	Kenya	Narok	1.183333	S	36.25	E	2090	21/9/1980
323	***K. laciniata***	Kenya	Baringo	1.233333	N	35.75	E	1067	10/1980
48	***K. laciniata***	Kenya	Baringo	0.716667	N	36.03333	E	-9999	1/11/1983
2416	***K. laciniata***	Kenya	<several>	1.566667	N	35.9	E	1555	17/11/1984
20844	***K. laciniata***	Kenya	Nakuru	0.416667	S	36.08333	E	1740	20/7/1975
62	***K. laciniata***	Kenya	Nakuru	0.766667	S	36.4	E	-9999	27/7/1966
1983	***K. laciniata***	Kenya	Muranga	0.783333	S	37.25	E	1128	29/12/1973
2068	***K. laciniata***	Kenya	Machakos	0.783333	S	37.75	E	900	12/5/1974
20289	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	1500	30/6/1973
247	***K. laciniata***	Kenya	Meru	0.116667	N	38.2	E	731	16/5/1972
20048	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	1554	15/10/1972
371	***K. laciniata***	Kenya	Thika	1.033333	S	37.08333	E	1520	11/7/1971
1541	***K. laciniata***	Kenya	Nairobi	1.283333	S	36.81667	E	1650	29/8/1970
69	***K. laciniata***	Kenya	Kitui	0		0		1050	22/8/1968
8352	***K. laciniata***	Kenya	Machakos	1.916667	S	37.55	E	1219	17/6/1966
5344	***K. laciniata***	Kenya	Machakos	1.483333	S	37.06667	E	-9999	15/1/1964
103	***K. laciniata***	Kenya	Machakos	0		0		1463	24/8/1947
1110	***K. laciniata***	Kenya	Machakos	2.466667	S	37.91667	E	1000	11/6/1977
2994	***K. laciniata***	Kenya	Machakos	2.35	S	38.05	E	914	1941
20	***K. laciniata***	Kenya	Machakos	0		0		1829	6/1939
1244	***K. laciniata***	Kenya	Machakos	2.35	S	38.05	E	914	23/7/1938
293	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	1707	7/6/1957
2115	***K. laciniata***	Kenya	Embu	0.6	S	37.75	E	1067	27/6/1932
1882	***K. laciniata***	Kenya	Nairobi	1.316667	S	36.75	E	1737	6/1932
8473	***K. laciniata***	Kenya	Machakos	2.35	S	38.05	E	914	19/3/1939

563	***K. laciniata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	21/7/1951
503	***K. laciniata***	Kenya	Machakos	1.666667	S	37.45	E	1875	3/8/1985
237	***K. laciniata***	Kenya	Nairobi	1.266667	S	36.83333	E	1676	7/8/1965
936	***K. laciniata***	Kenya	Machakos	1.75	S	37.38333	E	1890	11/5/1968
67/643	***K. laciniata***	Kenya	Thika	1.05	S	37.08333	E	-9999	16/6/1967
67/458	***K. laciniata***	Kenya	Thika	1.05	S	37.08333	E	1509	3/7/1967
s.n.	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	-9999	21/6/1969
699	***K. laciniata***	Kenya	Muranga	0.75	S	37	E	-9999	3/9/1972
457	***K. laciniata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	20/6/1952
1005	***K. laciniata***	Kenya	Nairobi	1.283333	S	36.81667	E	1524	12/8/1953
282	***K. laciniata***	Kenya	Machakos	1.5	S	37.16667	E	1768	28/8/1965
304	***K. laciniata***	Kenya	Kisumu	0.1	S	34.55	E	1158	6/8/1966
1739	***K. laciniata***	Kenya	Siaya	0.016667	S	34.35	E	-9999	30/12/1968
1137	***K. laciniata***	Kenya	<several>	2.5	S	38.33333	E	-9999	1/6/1969
543	***K. laciniata***	Kenya	Baringo	0		0		-9999	14/2/1960
566	***K. laciniata***	Kenya	Narok	1.25	S	35.58333	E	1875	28/1/1961
666	***K. laciniata***	Kenya	Narok	1.4	S	35.21667	E	1737	19/4/1961
1139	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	-9999	19/8/1973
1141	***K. laciniata***	Kenya	Narok	1.25	S	35.58333	E	-9999	19/8/1973
5132	***K. laciniata***	Kenya	Narok	1.6	S	35.63333	E	2100	27/8/1976
5295	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	1875	9/10/1976
6240	***K. laciniata***	Kenya	Narok	1.6	S	35.25	E	1675	27/5/1977
121	***K. laciniata***	Kenya	Kajiado	0		0		-9999	20/7/1979
7417	***K. laciniata***	Kenya	Narok	1.6	S	35.25	E	1700	8/9/1977
4082	***K. laciniata***	Kenya	Kajiado	1.85	S	36.78333	E	-9999	5/7/1977

909	***K. laciniata***	Kenya	Narok	0		0		1859	29/4/1961
1131	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	-9999	18/8/1973
1132	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	-9999	18/8/1973
1134	***K. laciniata***	Kenya	Narok	1.6	S	35.25	E	-9999	18/8/1973
10262	***K. laciniata***	Kenya	Narok	1.4	S	35.21667	E	-9999	9/1952
64/89	***K. laciniata***	Kenya	Kajiado	1.583333	S	36.45	E	1006	14/6/1964
71	***K. laciniata***	Kenya	Narok	1.4	S	35.21667	E	1829	9/1967
16	***K. laciniata***	Kenya	Narok	1.133333	S	35.08333	E	1890	12/2/1972
10601	***K. laciniata***	Kenya	Kajiado	1.85	S	36.78333	E	1737	30/6/1956
2654	***K. laciniata***	Kenya	Narok	1.25	S	35.58333	E	-9999	14/6/1971
2367	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	1868	8/8/1961
2364	***K. laciniata***	Kenya	Narok	1.15	S	35.76667	E	1868	8/8/1961
2211	***K. laciniata***	Kenya	Narok	1.85	S	35.83333	E	2225	14/7/1961
757	***K. laciniata***	Kenya	Narok	1.25	S	35.58333	E	1859	20/4/1961
678	***K. laciniata***	Kenya	Narok	1.4	S	35.21667	E	1737	19/4/1961
3860	***K. laciniata***	Kenya	Taita Taveta	3.416667	S	37.93333	E	975	7/8/1968
87	***K. laciniata***	Kenya	Taita Taveta	0		0		1189	11/7/1966
1774	***K. laciniata***	Kenya	West Pokot	1.45	N	35.35	E	-9999	12/1958
4029	***K. laciniata***	Kenya	Narok	1.666667	S	35.83333	E	2200	7/2/1997
4613	***K. laciniata***	Kenya	Makueni	1.716667	S	37.41667	E	1829	19/6/1997
1597	***K. laciniata***	Kenya	Baringo	0.966667	N	35.95	E	-9999	28/12/1977
240	***K. laciniata***	Kenya	Baringo	0.716667	N	36.03333	E	1000	5/11/1988
643	***K. laciniata***	Kenya	Thika	1.05	S	37.08333	E	-9999	16/8/1967
1798	***K. laciniata***	Kenya	Bungoma	0		0		3450	0
4613	***K. laciniata***	Kenya	Makueni	1.716667	S	37.41667	E	1829	19/6/1997

67458	***K. laciniata***	Kenya	Thika	1.033333	S	37.06667	E	1509	3/7/1967
s.n.	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	-9999	21/6/1969
003/25/2000	***K. laciniata***	Kenya	Machakos	1.566667	S	37.23333	E	1300	28/9/2000
s.n.	***K. laciniata***	Kenya	Nairobi	1.383333	S	36.85	E	-9999	21/6/1969
44	***K. laciniata***	Kenya	Thika	1.079167	S	37.04339	E	1535	25/6/2003
10783	***K. laciniata***	Kenya		0.916667	N	36.75	E	1790	0
20380	***K. lateritia***	Kenya	Garissa	1	S	40	E	40	26/8/1973
1618	***K. lateritia***	Kenya	Kitui	1.033333	S	38.01667	E	1200	5/5/1960
9760	***K. lateritia***	Kenya	Machakos	1.183333	S	37.55	E	1189	9/6/1954
718	***K. lateritia***	Kenya	Kisumu	0.166667	S	34.9	E	-9999	11/1939
158	***K. lateritia***	Kenya	Busia	0.016667	N	34	E	1200	9/1965
796	***K. lateritia***	Kenya	Kericho	0.683333	S	35.1	E	-9999	8/1956
1133	***K. lateritia***	Kenya	Narok	1.6	S	35.25	E	-9999	18/8/1973
2700	***K. lateritia***	Kenya	Narok	1.483333	S	35.1	E	1585	15/8/1971
1443	***K. lateritia***	Kenya	Narok	0.333333	S	35	E	-9999	0
10280	***K. lateritia***	Kenya	Kajiado	1.85	S	36.78333	E	-9999	1/1940
4850	***K. lateritia***	Kenya	Kajiado	2.55	S	36.76667	E	1750	17/9/1977
9665	***K. lateritia***	Kenya	Narok	1.483333	S	35.1	E	1725	18/9/1978
22723	***K. lateritia***	Kenya	Narok	0.333333	S	35	E	1480	22/8/1979
487	***K. lateritia***	Kenya	Narok	1.483333	S	35.1	E	1670	1/7/1986
5447	***K. lateritia***	Kenya	Narok	1.483333	S	35.1	E	1585	24/9/1947
13340	***K. lateritia***	Kenya	Taita Taveta	3.35	S	38.6	E	-9999	8/8/1969
651	***K. lateritia***	Kenya	Taita Taveta	3.4	S	38.4	E	900	18/5/1985
5361	***K. lateritia***	Kenya	Tana River	2.25	S	40.21667	E	18	6/8/1988
4925	***K. lateritia***	Kenya	Kilifi	3.25	S	39.71667	E	450	19/7/1987

2082	***K. lateritia***	Kenya	Kwale	3.966667	S	38.95	E	700	17/11/1989
5746	***K. lateritia***	Kenya	Kilifi	3.8	S	39.5	E	200	21/2/1989
5106	***K. lateritia***	Kenya	Kilifi	3.25	S	39.71667	E	450	16/2/1988
6516	***K. lateritia***	Kenya	Kwale	3.733333	S	39.13333	E	400	18/12/1991
2449	***K. lateritia***	Kenya	Kwale	3.733333	S	39.13333	E	400	18/9/1991
6201	***K. lateritia***	Kenya	Kwale	3.983333	S	39.53333	E	50	17/5/1990
1111	***K. lateritia***	Kenya	Taita Taveta	0		0		-9999	14/4/1973
1382	***K. lateritia***	Kenya	Taita Taveta	3.416667	S	38.4	E	-9999	10/11/1979
74/535	***K. lateritia***	Kenya	Taita Taveta	3.5	S	38.4	E	840	5/5/1974
16861	***K. lateritia***	Kenya	Kwale	3.8	S	39.41667	E	200	28/8/1965
948	***K. lateritia***	Kenya	Taita Taveta	3.6	S	38.46667	E	914	6/4/1931
6371	***K. lateritia***	Kenya	Kwale	3.733333	S	39.05	E	365	22/8/1948
10562	***K. lateritia***	Kenya	Taita Taveta	3.6	S	38.46667	E	-9999	8/5/1956
13946	***K. lateritia***	Kenya	Kwale	3.766667	S	39.26667	E	-9999	7/8/1970
1146	***K. lateritia***	Kenya	Kwale	0		0		150	3/9/1973
2032	***K. lateritia***	Kenya	Kwale	4.166667	S	39.16667	E	243	8/1929
1004	***K. lateritia***	Kenya	Taita Taveta	3.35	S	38.6	E	-9999	8/5/1964
70/150	***K. lateritia***	Kenya	Taita Taveta	3.633333	S	38.73333	E	760	31/5/1970
1237	***K. lateritia***	Kenya	Taita Taveta	3.383333	S	38.58333	E	-9999	1968
158	***K. lateritia***	Kenya	Kilifi	3.333333	S	39.86667	E	30	25/11/1983
734	***K. lateritia***	Kenya	Taita Taveta	3.833333	S	38.66667	E	-9999	10/5/1950
4577	***K. lateritia***	Mozambique	Niassa	0		0		-9999	17/7/1948
72	***K. lateritia***	Tanzania	Unknown	0		0		-9999	14/1/1960
1958	***K. lateritia***	Tanzania	Musoma	1.566667	S	34.85	E	1400	11/12/1973
1705	***K. lateritia***	Tanzania	Lushoto	5.1	S	38.63333	E	-9999	27/8/1929

447	***K. lateritia***	Tanzania	Lushoto	4.85	S	38.36667	E	1200	9/9/1972
1983	***K. lateritia***	Tanzania	Moshi	0		0		884	14/7/1968
4054	***K. lateritia***	Tanzania	Lushoto	0		0		1219	6/9/1935
1763	***K. lateritia***	Tanzania	Lushoto	5.1	S	38.63333	E	-9999	1/10/1929
3325	***K. lateritia***	Tanzania	Pangani	5.583333	S	38.75	E	1	13/7/1953
6100	***K. lateritia***	Tanzania	Lushoto	5.033333	S	38.61667	E	-9999	1966
19	***K. lateritia***	Tanzania	Lushoto	0		0		-9999	16/9/1935
945	***K. lateritia***	Tanzania	Lushoto	0		0		304	21/8/1967
1673	***K. lateritia***	Tanzania	Pare	4.366667	S	37.88333	E	1524	8/1928
2910	***K. lateritia***	Tanzania	Lushoto	0		0		1000	14/6/1953
1341	***K. lateritia***	Tanzania	Unknown	0		0		365	29/9/1970
6477	***K. lateritia***	Tanzania	Lushoto	5.1	S	38.63333	E	-9999	9/1911
1995	***K. lateritia***	Tanzania	Pare	4.583333	S	37.73333	E	-9999	1/10/1979
1323	***K. lateritia***	Tanzania	Lushoto	5.033333	S	38.33333	E	-9999	16/121935
6617	***K. lateritia***	Tanzania	Tanga	5.066667	S	39.05	E	30	11/8/1942
6502	***K. lateritia***	Tanzania	Pare	4.3	S	37.85	E	853	29/6/1942
2187	***K. lateritia***	Tanzania	Lushoto	4.783333	S	38.28333	E	-9999	8/1955
6478	***K. lateritia***	Tanzania	Lushoto	5.1	S	38.63333	E	-9999	10/1916
1762	***K. lateritia***	Tanzania	Lushoto	5.1	S	38.63333	E	-9999	1/10/1929
1492	***K. lateritia***	Tanzania	Pare	4.366667	S	37.88333	E	1524	8/1928
4826	***K. lateritia***	Tanzania	Handeni	5.75	S	37.88333	E	1067	6/9/1933
4939	***K. lateritia***	Tanzania	Tanga	0		0		15	9/6/1937
560	***K. lateritia***	Tanzania	Kigoma	5.466667	S	29.75	E	-9999	6/6/1963
9062	***K. lateritia***	Tanzania	Kigoma	4.883333	S	29.65	E	-9999	2/9/1941
464	***K. lateritia***	Tanzania	Morogoro	6.833333	S	37.66667	E	396	1/8/1935

292	***K. lateritia***	Tanzania	Lushoto	6.25	S	36.83333	E	1400	10/9/1990
839	***K. lateritia***	Tanzania	Kilosa	6.333333	S	37	E	1524	20/12/1967
2910	***K. lateritia***	Tanzania	Morogoro	6.833333	S	37.66667	E	-9999	31/12/1939
196	***K. lateritia***	Tanzania	Ulanga	9.283333	S	37	E	396	8/7/1972
254	***K. lateritia***	Tanzania	Morogoro	6.833333	S	37.66667	E	548	28/7/1954
299	***K. lateritia***	Tanzania	Morogoro	6.683333	S	37.95	E	365	28/6/1955
24/29	***K. lateritia***	Tanzania	Lushoto	5	S	38.45	E	-9999	23/9/1929
1321	***K. lateritia***	Tanzania	Rufiji/Ulanga/Kilwa	8.583333	S	38.25	E	2000	10/6/1971
1078	***K. lateritia***	Tanzania	Rufiji/Ulanga/Kilwa	8.583333	S	38.25	E	-9999	16/7/1970
10125	***K. lateritia***	Tanzania	Songea	10.683333	S	35.65	E	1000	29/6/1956
2871	***K. lateritia***	Tanzania	Lindi	0		0		-9999	14/6/1903
3238	***K. lateritia***	Rwanda	Biumba	0		0		-9999	24/5/1957
2645	***K. lateritia***	Burundi	Muramwya	0		0		1700	9/9/1973
21	***K. lateritia***	Kenya	Kilifi	3.2	S	39.52	E	-9999	1991
2659	***K. lateritia***	Kenya	Taita Taveta	3.28	S	38.17	E	1150	16/8/1999
21	***K. lateritia***	Kenya	Kilifi	3.2	S	39.52	E	-9999	1991
2659	***K. lateritia***	Kenya	Taita Taveta	3.28	S	38.17	E	1150	16/8/1999
6002	***K. lateritia***	Kenya	Kwale	4.1	S	39.45	E	250	14/11/1989
2269	***K. lateritia***	Kenya	Kilifi	3.916667	S	39.58333	E	90	22/5/1990
3790	***K. lateritia***	Kenya	Kwale	4.45	S	39.48333	E	100	14/8/1953
s.n.	***K. lateritia***	Tanzania	Lushoto	5.05	S	38.63333	E	-9999	27/3/1974
3790	***K. lateritia***	Kenya	Kwale	4.65	S	39.21667	E	100	14/8/1953
10898	***K. lateritia***	Tanzania	Masai	2.733333	S	36.7	E	-9999	9/10/1963
1253	***K. lateritia***	Kenya	Kwale	3.733333	S	39.35	E	-9999	16/1/1941
11455	***K. lateritia***	Kenya	Kericho	0.683333	S	35.1	E	1829	1956

11455	***K. lateritia***	Kenya	Kericho	0.683333	S	35.11667	E	1829	1956
115	***K. lugardii***	Kenya	Trans-Nzoia	1.133333	N	34.55	E	2134	10/1930
1875	***K. marmorata***	Kenya	Marsabit	3.5	N	37.85	E	1100	11/3/1979
59	***K. marmorata***	Kenya	Samburu	0.833333	N	37.53333	E	1829	5/2/1969
2644	***K. marmorata***	Kenya	Samburu	0		0		2134	9/12/1960
116/50	***K. marmorata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	23/11/1950
5014	***K. marmorata***	Kenya	Garissa	0.35	S	39.73333	E	-9999	1946
2678	***K. marmorata***	Kenya	Kajiado	1.416667	S	36.63333	E	1829	6/1933
5393	***K. marmorata***	Kenya	Narok	1.916667	S	35.7	E	2125	10/10/1976
2321	***K. marmorata***	Kenya	Narok	0.933333	S	35.06667	E	2164	2/8/1961
13957	***K. marmorata***	Kenya	Marsabit	3.7	N	38.01667	E	-9999	9/1952
3584	***K. marmorata***	Kenya	Samburu	0		0		-9999	1/1959
162	***K. marmorata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	16/2/1951
1390	***K. marmorata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	6/1934
3237	***K. marmorata***	Kenya	Nairobi	1.283333	S	36.81667	E	-9999	6/1934
15107	***K. mitejea***	Kenya	Laikipia	0.5	N	36.75	E	1800	15/6/1972
219	***K. mitejea***	Kenya	West Pokot	1.4	N	35.5	E	-9999	23/2/1978
21832	***K. mitejea***	Kenya	Baringo	0.283333	N	35.9	E	1440	27/4/1979
19769	***K. mitejea***	Kenya	Kitui	1.85	S	38.21667	E	950	1/6/1972
3196	***K. mitejea***	Kenya	Machakos	2.683333	S	38.16667	E	-9999	28/6/1961
21383	***K. mitejea***	Kenya	Kitui	0		0		840	3/7/1977
15221	***K. mitejea***	Kenya	Kitui	1.85	S	38.21667	E	950	12/8/1972
63	***K. mitejea***	Kenya	Machakos	2.083333	S	37.48333	E	1676	10/3/1940
1920	***K. mitejea***	Kenya	Machakos	0.783333	S	37.65	E	1070	18/11/1973
13533	***K. mitejea***	Kenya	Taita Taveta	3.45	S	38.31667	E	-9999	1/9/1969

2362	***K. mitejea***	Kenya	Taita Taveta	3.416667	S	37.93333	E	914	20/4/1968
177	***K. mitejea***	Kenya	Machakos	2.35	S	38.05	E	800	21/6/1906
3500	***K. mitejea***	Kenya	Isiolo	0.35	N	37.58333	E	1067	1942
556	***K. mitejea***	Kenya	Baringo	0.466667	N	35.98333	E	-9999	1959
1054	***K. mitejea***	Kenya	Meru	0		0		-9999	3/1972
1101	***K. mitejea***	Kenya	Kajiado/Teita/Moshi	3.05	S	37.76667	E	-9999	8/4/1973
31	***K. mitejea***	Kenya	Garissa	0.35	S	39.73333	E	-9999	0
46	***K. mitejea***	Kenya	West Pokot	1.433333	N	35.41667	E	2743	30/6/1978
2841	***K. mitejea***	Kenya	Taita Taveta	2.483333	S	37.73333	E	1150	14/6/1991
2841	***K. mitejea***	Kenya	Kajiado	2.483333	S	37.73333	E	1150	8/6/1991
151	***K. mitejea***	Kenya	Meru	0.1	N	37.25	E	1740	29/7/2001
539	***K. ndotoensis***	Kenya	Samburu	1.716667	N	37.28333	E	1220	9/1978
2657	***K. ndotoensis***	Kenya	Taita Taveta	3.28	S	38.27	E	1040	16/8/1999
2657	***K. ndotoensis***	Kenya	Taita Taveta	3.28	S	38.27	E	1040	16/8/1999
1079/1	***K. nyikae*** aur. x ***glaucescens***	Kenya	Narok	0		0		-9999	3/1972
10760	***K. nyikae***	Tanzania	Musoma	0		0		1646	19/8/1962
1247	***K. nyikae***	Tanzania	Moshi	3.066667	S	37.36667	E	1432	22/7/1967
2601	***K. nyikae***	Kenya	Makueni	1.983333	S	37.36667	E	1615	7/1943
13771	***K. nyikae***	Kenya	Taita Taveta	0		0		-9999	26/8/1969
316	***K. nyikae***	Kenya	Machakos	2.083333	S	37.48333	E	1524	7/1940
380	***K. nyikae***	Kenya	Machakos/Kajiado	2.566667	S	37.83333	E	1219	25/4/1938
14412	***K. nyikae***	Kenya	Narok	1.666667	S	35.66667	E	-9999	21/1/1981
1068	***K. nyikae***	Kenya	Machakos/Kajiado	2.566667	S	37.83333	E	1524	17/7/1938
10209	***K. nyikae***	Kenya	Narok	1.083333	S	35.86667	E	-9999	16/7/1968
16174	***K. nyikae***	Kenya	Narok	1.183333	S	35.25	E	1800	10/9/1964

1144	***K. nyikae***	Kenya	Narok	1.083333	S	35.86667	E	-9999	19/8/1973
1129	***K. nyikae***	Kenya	Narok	1.1	S	35.86667	E	-9999	18/8/1973
5429	***K. nyikae***	Kenya	Narok	1.483333	S	35.1	E	1585	21/9/1947
9002	***K. nyikae***	Kenya	Kajiado	1.7	S	36.43333	E	1707	8/1943
404	***K. nyikae***	Kenya	Taita Taveta	3.583333	S	38.5	E	914	0
1080	***K. nyikae***	Kenya	Machakos	2.35	S	38.05	E	-9999	3/1972
1079/2	***K. nyikae***	Kenya	Narok	0		0		-9999	3/1972
213	***K. nyikae***	Kenya	Kajiado	2.933333	S	37.5	E	-9999	31/3/1960
13469	***K. nyikae***	Kenya	Taita Taveta	0		0		700	28/8/1969
2009	***K. nyikae***	Kenya	Taita Taveta	3.4	S	38.38333	E	-9999	3/9/1962
10760	***K. nyikae***	Tanzania	Musoma	0		0		1646	19/8/1962
2208	***K. nyikae***	Tanzania	Moshi	3.316667	S	37.21667	E	1006	21/9/1968
6695	***K. nyikae***	Tanzania	Pare/Lushoto	4.8	S	38.23333	E	609	1/6/1943
2017	***K. nyikae***	Kenya	Kwale	3.966667	S	38.95	E	500	17/11/1989
2223	***K. nyikae***	Kenya	Kilifi	3.233333	S	39.71667	E	270	29/3/1990
2555	***K. nyikae***	Kenya	Kilifi	2.883333	S	39.65	E	300	1/12/1990
248	***K. nyikae***	Kenya	Kilifi	3.25	S	39.71667	E	304	9/1950
28616	***K. nyikae***	Kenya	Kilifi	3.183333	S	39.68333	E	-9999	25/3/1989
70/151	***K. nyikae***	Kenya	Taita Taveta	3.633333	S	38.73333	E	760	31/5/1970
3918	***K. nyikae***	Tanzania	Lushoto/Tanga	0		0		-9999	0
1220	***K. nyikae***	Uganda	Mengo	1.1	N	32.88333	E	-9999	8/1975
13367	***K. nyikae***	Kenya	Taita Taveta	3.383333	S	38.58333	E	-9999	8/1969
s.n.	***K. nyikae***	Tanzania	Pare	4.066667	S	37.73333	E	914	15/1/1945
11376	***K. nyikae***	Tanzania	Pare	0		0		609	23/1/1957
12472	***K. nyikae***	Kenya	Taita Taveta	3.366667	S	38.13333	E	-9999	14/2/1969

1185	***K. nyikae***	Tanzania	Pare	4.333333	S	37.85	E	-9999	8/1975
7993	***K. nyikae***	Kenya	Kilifi	3.25	S	39.71667	E	-9999	9/1950
6480	***K. obtusa***	Kenya	Kwale	4.133333	S	39.46667	E	300	16/8/1991
5764	***K. obtusa***	Kenya	Kwale	4.1	S	39.45	E	340	9/7/1989
5442	***K. obtusa***	Kenya	Kilifi	3.25	S	39.88333	E	450	3/9/1988
6192	***K. obtusa***	Kenya	Kwale	3.983333	S	39.53333	E	60	17/5/1990
2477	***K. obtusa***	Kenya	Kilifi	3.033333	S	39.8	E	120	24/11/1992
4209	***K. obtusa***	Kenya	Kwale	0		0		-9999	19/7/1986
1931	***K. obtusa***	Kenya	Kilifi	3.85	S	39.66667	E	150	17/8/1989
2029	***K. obtusa***	Kenya	Kilifi	3.333333	S	39.86667	E	-9999	1929
1895	***K. obtusa***	Kenya	Kilifi	3.333333	S	39.86667	E	-9999	2/1929
535	***K. obtusa***	Kenya	Kilifi	3.416667	S	39.8	E	-9999	17/7/1946
10282	***K. obtusa***	Kenya	Nyeri	0.533333	S	36.98333	E	-9999	20/8/1951
s.n.	***K. obtusa***	Kenya	Mombasa	3.983333	S	39.6	E	-9999	10/1888
s.n.	***K. obtusa***	Kenya	Kilifi	3.933333	S	39.56667	E	-9999	9/1888
2799	***K. pinnata***	Kenya	Trans Nzoia	1.033333	S	35.31667	E	1920	1/1958
644	***K. pinnata***	Kenya	Trans Nzoia	0.65	N	34.85	E	1676	12/1931
40	***K. prittwitzii***	Kenya	Trans Nzoia	1.1	N	34.76667	E	1890	8/10/1968
300	***K. prittwitzii***	Kenya	Nairobi	1.266667	S	36.76667	E	1660	8/8/1977
126	***K. prittwitzii***	Kenya	Nyeri	0.533333	S	36.98333	E	-9999	8/1951
473	***K. prittwitzii***	Kenya	Laikipia	0.016667	N	37.06667	E	2500	12/2/1960
3155	***K. prittwitzii***	Kenya	Laikipia	0.016667	N	37.06667	E	-9999	5/7/1961
226	***K. prittwitzii***	Kenya	Unknown	0		0		2286	7/7/1943
2185	***K. prittwitzii***	Kenya	Nyeri	0.233333	S	37.03333	E	1829	1/8/1932
20294	***K. prittwitzii***	Kenya	Nairobi	1.283333	S	36.81667	E	1737	22/7/1973

8268	***K. prittwitzii***	Kenya	Laikipia	0.05	S	36.78333	E	-9999	22/4/1952
320/03/1	***K. prittwitzii***	Kenya	Nairobi	1.266667	S	36.83333	E	-9999	19/9/1963
461	***K. prittwitzii***	Kenya	Siaya	0.116667	S	34.21667	E	1981	11/10/1956
1066	***K. prittwitzii***	Kenya	Kericho	0.3	S	35.2	E	-9999	3/1972
2109	***K. prittwitzii***	Kenya	Narok	1.816667	S	35.88333	E	2225	13/7/1961
58	***K. prittwitzii***	Kenya	Samburu	0.833333	N	37.53333	E	1829	5/2/1969
62	***K. prittwitzii***	Kenya	Samburu	0.833333	N	37.53333	E	1829	5/2/1969
984	***K. prittwitzii***	Kenya	Turkana	3.166667	N	35.01667	E	2134	21/9/1963
7131	***K. prittwitzii***	Kenya	Turkana	3.166667	N	35	E	2134	15/2/1965
41	***K. prittwitzii***	Kenya	West Pokot	1.25	N	35.11667	E	2000	9/10/1968
975	***K. prittwitzii***	Kenya	Baringo	0.1	S	35.76667	E	-9999	10/1932
643	***K. prittwitzii***	Kenya	Uasin Gishu/Nandi	0		0		1676	12/1931
396	***K. prittwitzii***	Kenya	Bungoma	0		0		2134	1/1/1933
8721	***K. prittwitzii***	Kenya	Trans Nzoia	1.1	N	34.76667	E	1981	6/1942
8722	***K. prittwitzii***	Kenya	Trans Nzoia	1.1	N	34.76667	E	1951	6/1942
52	***K. prittwitzii***	Kenya	Trans Nzoia	1.216667	N	34.76667	E	2150	18/2/1948
245	***K. prittwitzii***	Kenya	Bungoma	0		0		2042	13/11/1957
555	***K. prittwitzii***	Kenya	Baringo	0.466667	N	35.98333	E	-9999	16/2/1960
124	***K. prittwitzii***	Kenya	Baringo	0.483333	N	35.75	E	2073	10/1978
115	***K. prittwitzii***	Kenya	Bungoma	0		0		2134	10/1930
9107	***K. prittwitzii***	Kenya	Marsabit	3.516667	N	39.05	E	-9999	9/1953
1775	***K. prittwitzii***	Kenya	West Pokot	1.45	N	35.35	E	-9999	12/1958
s.n.	***K. prittwitzii***	Kenya	Samburu	1.15	N	36.68333	E	-9999	3/1955
6253	***K. prittwitzii***	Kenya	Uasin Gishu	0.516667	N	35.26667	E	2286	17/1/1948
3993	***K. prittwitzii***	Kenya	Narok	1.666667	S	35.83333	E	2200	5/2/1997

1317	***K. prittwitzii***	Kenya	Nandi	0.1	N	35.18333	E	-9999	16/12/2007
8722	***K. prittwitzii***	Kenya	Trans Nzoia	1.1	N	34.76667	E	1951	6/1942
8721	***K. prittwitzii***	Kenya	Trans Nzoia	1.1	N	34.76667	E	1981	6/1942
643	***K. prittwitzii***	Kenya	Trans Nzoia	0.65	N	34.85	E	1676	12/1931
2666	***K. prittwitzii***	Kenya	Taita Taveta	3.28	S	38.18	E	1350	19/8/1999
14182	***K. prittwitzii***	Kenya	Samburu	1.1585	N	37.3478	E	1760	0
2666	***K. prittwitzii***	Kenya	Taita Taveta	3.28	S	38.18	E	1350	19/8/1999
14182	***K. prittwitzii***	Kenya	Samburu	1.1585	N	37.3478	E	1760	0
14182	***K. prittwitzii***	Kenya	Samburu	1.1585	N	37.3478	E	1760	7/6/2010
14358	***K. rotundifolia***	Kenya	Makueni	2.4554	S	37.9012	E	1005	0
14358	***K. rotundifolia***	Kenya	Makueni	2.4554	S	37.9012	E	1005	0
2839	***K. rotundifolia***	Kenya	Kajiado	2.466667	S	37.71667	E	1150	8/6/1991
14358	***K. rotundifolia***	Kenya	Makueni	2.4554	S	37.9012	E	1005	14/8/2010
1647	***K. rotundifolia*** x glauc.	Kenya	Taita Taveta	3.583333	S	38.5	E	900	27/11/1985
860	***K. rotundifolia*** x glauc.	Kenya	Kilifi	3.133333	S	39.98333	E	-9999	1959
2048	***K. rotundifolia*** x glauc.	Kenya	Taita Taveta	3.366667	S	38.13333	E	-9999	1/9/1962
423	***Kalanchoe*** sp	Kenya	Tana River	1.883333	S	40.11667	E	35	15/3/1990
1475	***Kalanchoe*** sp	Kenya	Lamu	1.766667	S	40.85	E	35	24/11/1988
3535	***Kalanchoe*** sp	Kenya	Kajiado	2.533333	S	37.51667	E	1100	27/3/1993
003/67/2000	***Kalanchoe*** sp	Kenya	Machakos	1.066667	S	37.23333	E	1130	3/10/2000
15465	***Kalanchoe*** sp	Tanzania	Kilosa	7.433333	S	37.11667	E	609	9/7/1973
1303	***Kalanchoe*** sp	Tanzania	Rufiji/Ulanga/Kilwa	8.666667	S	38.41667	E	800	14/6/1971
3708	***Kalanchoe*** sp	Tanzania	Rufiji	7.8	S	37.9	E	-9999	5/8/1993
1118	***Kalanchoe*** sp	Kenya	Garissa	1.15	S	41.2	E	-9999	1940
1475	***Kalanchoe*** sp	Kenya	Lamu	1.766667	S	40.85	E	35	24/11/1988
5899	***Kalanchoe*** sp	Kenya	Lamu	1.75	S	40.85	E	700	24/11/1988

6495	***Kalanchoe*** sp	Kenya	Lamu	1.766667	S	40.85	E	35	24/11/1988
2695	***Kalanchoe*** sp	Kenya	Lamu	1.733333	S	40.86667	E	-9999	27/7/2006
6E	***K. lanceolata***	Kenya	Machakos	1.24398	S	37.3119	E	1251m	21/8/2019
28	***K. lanceolata***	Kenya	Machakos	1.2118	S	37.5652	E	1167m	21/8/2019
YKR	***K. lanceolata***	Kenya	Taita Taveta	1.1228	S	37.5843	E	1238m	21/8/2019
29	***K. lateritia***	Kenya	Taita Taveta	1.22309	S	38.33411	E	681m	23/8/2019
29A	***K. lateritia***	Kenya	Taita Taveta	1.22309	S	38.33411	E	681m	23/8/2019
30	***K. lanceolata***	Kenya	Taita Taveta	3.48206	S	38.391	E	731m	23/8/2019
31	***K. lanceolata***	Kenya	Taita Taveta	3.48222	S	38.39106	E	738m	23/8/2019
32	***K. lanceolata***	Kenya	Taita Taveta	3.22399	S	38.234	E	998m	24/8/2019
33	***K. lateritia***	Kenya	Taita Taveta	3.2338	S	38.23188	E	933m	24/8/2019
33A	***K. lateritia***	Kenya	Taita Taveta	3.23382	S	38.23188	E	933m	24/8/2019
34	***K. lateritia***	Kenya	Taita Taveta	3.2435	S	38.23415	E	858m	24/8/2019
34A	***K. lateritia***	Kenya	Taita Taveta	3.2435	S	38.23415	E	858m	24/8/2019
35	***K. lateritia***	Kenya	Taita Taveta	3.24348	S	38.23412	E	861m	26/8/2019
37	***K. lateritia***	Kenya	Taita Taveta	3.29412	S	38.18243	E	959m	24/8/2019
37A	***K. lateritia***	Kenya	Taita Taveta	3.29412	S	38.18243	E	959m	24/8/2019
39	***K. denisflora***	Kenya	Taita Taveta	3.22268	S	38.2025	E	1734m	25/8/2019
40	***K. lateritia***	Kenya	Kwale	4.05571	S	39.26258	E	137m	26/8/2019
41	***K. lateritia***	Kenya	Kwale	4.05092	S	39.31229	E	15m	25/8/2019
41A	***K. lateritia***	Kenya	Kwale	4.05092	S	39.31229	E	15m	25/8/2019
38	***K. lateritia***	Kenya	Kwale	4.05571	S	39.26258	E	137m	26/8/2019
38A	***K. lateritia***	Kenya	Kwale	4.05571	S	39.26258	E	137m	26/8/2019
42	***K. lateritia***	Kenya	Kwale	4.05092	S	39.31229	E	15m	26/8/2019
42A	***K. lateritia***	Kenya	Kwale	4.05092	S	39.31229	E	15m	26/8/2019

43	***K. crenata***	Kenya	Kakamega	0.693608	S	35.03034	E		25/8/2019
44	***K. crenata***	Kenya	Kakamega	0.59184	S	34.8303	E		25/11/2019
45	*K. crenata*	Kenya	Kakamega	0.617207	S	34.96882	E		25/11/2019
46	*K. crenata*	Kenya	Bungoma	0.620077	S	34.55379	E		27/11/2019
47	*K. prittwitzi*i	Kenya	Bungoma	0.620077	S	34.55379	E		27/11/2019
48	*K. crenata*	Kenya	Bungoma	0.558115	S	34.58882	E		28/11/2019
49	*K. prittwitzii* Engl.	Kenya	Bungoma	0.490347	S	34.62147	E		29/11/2019
49A	*K. prittwitzii* Engl.	Kenya	Bungoma	0.490347	S	34.62147	E		29/11/2019
50	*K. crenata*	Kenya	Bungoma	0.490255	S	34.62068	E		29/11/2019
51	*K. prittwitzii* Engl.	Kenya	Bungoma	0.614022	S	34.38123	E		29/11/2019
52	*K. prittwitzii* Engl.	Kenya	Busia	0.611488	S	34.35934	E		30/11/2019
53	*K. glaucescens*	Kenya	Busia	0.145935	S	34.07687	E		30/1/2019
55	*K. glaucescens*	Kenya	Busia	0.145388	S	34.07672	E	1668m	30/1/2019
55A	*K. glaucescens*	Kenya	Busia	0.145388	S	34.07672	E	1668m	30/1/2019
55C	*K. glaucescens*	Kenya	Busia	0.145388	S	34.07672	E	1668m	30/1/2019
57	*K. prittwitzii* Engl.	Kenya	Busia	0.145388	S	34.07672	E	1668m	30/11/2019
58	*K.*cf *lateritia* Engl.	Kenya	Busia	0.147325	S	34.08011	E		30/11/2019
60	*K. crenata*	Kenya	Vihiga	0.122655		34.7735	E		11/12/2019
61	*K. crenata*	Kenya	Bungoma	0.44166	N	34.41243	E	1536m	14/12/2019
62	*K. crenata*	Kenya	Bungoma	0.947348	N	43.49553	E	1732m	14/12/2019
63	*K. crenata*	Kenya	Trans Nzoia	0.54155	N	34.54425	E		14/12/2019
64	*K. crenata*	Kenya	Trans Nzoia	0.58003	N	34.51089	E	1850m	14/12/2019
65	*K. prittwitzii* Engl.	Kenya	Trans Nzoia	0.58342	N	34.5056	E	1837m	14/12/2019
66	*K. densiflora*	Kenya	Trans Nzoia	0.58344	N	34.50561	E	1836	29/1/2019
65	*K. prittwitzii*	Kenya	Trans Nzoia	0.58366	N	34.50538	E	1844m	14/12/2019

67	*K .crenata*	Kenya	Trans Nzoia	0.58372	N	34.50515	E	1836m	14/12/2019
68	*K. densiflora*	Kenya	Trans Nzoia	0.58539	N	34.50209	E	1829m	14/12/2019
69	*K. densiflora*	Kenya	Trans Nzoia	1.02134	N	34.47587	E	2120m	14/12/2019
70	*K. crenata*	Kenya	Trans Nzoia	1.02176	N	34.48316	E	2090m	14/12/2019
71	*K. densiflora*	Kenya	Trans Nzoia	1.02256	N	34.51172	E	1912m	14/12/2019
72A	*K. lanceolata*	Kenya	West Pokot	1.16529	N	35.09177	E	2182m	15/12/2019
73	*K. prittwitzii* Engl.	Kenya	West Pokot	1.17211	N	35.0942	E	2260m	15/12/2019
74A	*K. lanceolata*	Kenya	West Pokot	1.17526	N	35.11319	E	1780m	15/12/2019
75	*K. prittwitzii* Engl.	Kenya	West Pokot	1.18354	N	35.12433	E	1747m	15/12/2019
76	*K. prittwitzii* Engl.	Kenya	West Pokot	1.25514	N	35.21099	E	1442 m	15/12/2019
77	*K. lanceolata*	Kenya	West Pokot	1.23597	N	35.1955	E	1457m	15/12/2019
78A	*K. prittwitzii* Engl.	Kenya	West Pokot	1.24005	N	35.19552	E	1458m	15/12/2019
80	*K. crenata*	Kenya	West Pokot	1.12481	N	45.05056	E	2002m	15/12/2019
79	*K. densiflora*	Kenya	West Pokot	1.12467	N	35.05045	E	1975m	15/12/2019
81	*K. lanceolata*	Kenya	Elgeyo Marakwet	0.37505	N	35.31133	E	1983m	16/12/2019
82A	*K. prittwitzii* Engl.	Kenya	Elgeyo Marakwet	0.33324	N	35.31266	E	1761m	16/12/2019
83A	*K .prittwitzii* Engl.	Kenya	Elgeyo Marakwet	0.33324	N	35.31261	E	1761m	16/12/2019
84	*K.* cf *prittwitzii* Engl.	Kenya	Baringo	0.29353	N	35.43196	E	1802m	16/12/2019
85	*K.* prittwitzii Engl.	Kenya	Baringo	0.293364	N	35.43206	E	1819m	16/12/2019
85A	*K prittwitzii* Engl.	Kenya	Baringo	0.293364	N	35.43206	E	1819m	16/12/2019
86	*K. prittwitzii* Engl.	Kenya	Baringo	0.29364	N	35.43206	E	1821m	16/12/2019
87	*K. lanceolata*	Kenya	Baringo	0.27457	N	35.58295	E	1077m	16/12/2019
88	*K. mitejea*	Kenya	Baringo	0.25414	N	35.57483	E	1157m	16/12/2019
89	*K. lanceolata*	Kenya	Baringo	0.25423	N	35.57467	E	1162m	16/12/2019
90	*K. citrina*	Kenya	Baringo	0.1505	N	35.53596	E	1162m	16/12/2019

91	*K. citrina*	Kenya	Baringo	0.00304	N	35.57104	E	1567m	16/12/2019
92	*K.mitejea*	Kenya	Baringo	0.25414	N	35.57483	E	1157m	16/12/2019
93A	*K. densiflora*	Kenya	Nakuru	0.05176	S	36.10056	E	2248m	17/12/2019
93B	*K. densiflora*	Kenya	Nakuru	0.05176	S	36.10056	E	2248m	17/12/2019
94A	*K. densiflora*	Kenya	Nyandarua	0.01548	N	36.23372	E	2348m	17/12/2019
94B	*K. densiflora*	Kenya	Nyandarua	0.01548	N	36.23372	E	2348m	17/12/2019
95A	*K. densiflora*	Kenya	Nyahururu	0.02343	N	36.22162	E	2344m	17/12/2019
96	*K. densiflora*	Kenya	Nakuru	0.12048	S	35.50192		1953m	17/12/2019
96A	*K. densiflora*	Kenya	Nakuru	0.12048	S	35.50192		1953m	17/12/2019
97	*K. densiflora*	Kenya	Kericho	0.13122	S	35.33418		2155m	18/12/2019
98	*K. densiflora*	Kenya	Kericho	6.00125	S	35.24569	E		18/12/2019
100	*K. crenata*	Kenya	Bomet	0.874468		35.12076			18/12/2019
99	*K. densiflora*	Kenya	Bomet	0.874517		35.11807			18/12/2019
101	*K. densiflora*	Kenya	Bomet	0.763845		35.08248			18/12/2019
102	*K. densiflora*	Kenya	Bomet	6.129905	S	35.64778	E		19/12/2019
103	*K. densiflora*	Kenya	Bomet	-0.607018		35.05885			14/12/2019
104	*K. densiflora*	Kenya	Bomet	-0.69083		35.07663			19/12/2019
105	*K. crenata*	Kenya	Bomet	0.781235		35.13877			19/12/2019
106	*K. lateritia* Engl.	Kenya	Bomet	0.77125		35.13724			19/12/2019
107	*K. densiflora*	Kenya	Bomet	0.765597		35.13441			19/12/2019
108	*K. lanceolata*	Kenya	Narok	1.05398	S	35.55219		1816m	31/11/2020
109	*K. lanceolata*	Kenya	Narok	1.28485	S	35.5008`	E	1938m	24/11/2020
110	*K. lanceolata*	Kenya	Narok	1.28485	S	35.5008`	E	1938m	24/11/2020
112	*K. lanceolata*	Kenya	Narok	1.28485	S	35.51324	E	1972m	24/11/2020
113	*K. densiflora*	Kenya	Narok	1.37321	S	35.51297	E	2013m	21/1/2019

114	*K. densiflora*	Kenya	Narok	1.3854	S	35.51514	E	2247m	24/11/2020
115	*K. densiflora*	Kenya	Narok	1.4142	S	35.50077	E	2212m	24/11/2020
116	*K. glaucescens*	Kenya	Narok	1.42242	S	35.4849	E	2194m	24/11/2020
117	*K. glaucescens*	Kenya	Narok	1.47267	S	35.46201	E	2129m	24/11/2020
118	*K. marmorata*	Kenya	Narok	1.41074	S	35.49366	E	2501m	24/11/2020
119	*K. densiflora*	Kenya	Narok	1.41131	S	35.49278	E	2441m	25/11/2020
120	*K. marmorata*	Kenya	Narok	1.41061	S	35.49378	E	2520m	25/11/2020
121	*K. densiflora*	Kenya	Narok	1.41097	S	35.49283	E	2544m	25/11/2020
122	*K. densiflora*	Kenya	Narok	1.41448	S	35.49573	E	2201	25/11/2020
123	*K. lanceolata*	Kenya	Narok	1.31239	S	35.20278	E	1735m	26/11/2020
111	*K. citrina*	Kenya	Narok	1.34146	S	35.51596	E	1859m	21/1/2019
131	*K. densiflora*	Kenya	Narok	1.06369	S	35.49133	E	1892	27/11/2020
132	*K. glaucescens*	Kenya	Narok	1.08288	S	36.20079	E	1851m	27/11/2020
133	*K.* cf *lateritia*	Kenya	Narok	1.08271	S	36.20064	E		27/11/2020
124	*K. lanceolata*	Kenya	Narok	1.31231	S	35.2027		1716m	26/11/2020
125	*K. glaucescens*	Kenya	Narok	1.31233	S	35.20268	E	1740m	26/11/2020
126	*K. lanceolata*	Kenya	Narok	1.31239	S	35.20278	E	1736m	26/11/2020
127	*K. lanceolata*	Kenya	Narok	1.31233	S	35.20205	E	1740m	26/11/2020
128	*K. glaucescens*	Kenya	Narok	0.133139	S	35.21536	E	1835m	26/11/2020
129	*K. glaucescens*	Kenya	Narok	1.21046	S	35.42297	E	2072m	26/11/2020
130	*K. glaucescens*	Kenya	Narok	1.21185	S	35.42365	E	2149m	25/11/2020
134	*K. lanceolata*	Kenya	Narok	1.08093	S	36.1959	E	1859m	27/11/2020
134/7	*K. densiflora*	Kenya	Narok	1.05248	S	35.57153	E	1860m	27/11/2020
135	*K. glaucescens*	Kenya	Narok	1.17566	S	35.41022	E	1901m	26/11/2019
136	*K. glaucescens*	Kenya	Narok	1.2049	S	35.42164	E	2013	26/11/2019

1	*K. glaucescens*	Kenya	Kajiado	1.27248	S	36.38326	E	2000m	11/8/2019
465	*K. prittwitzii* Engl.	Kenya	Kajiado	1.27248	S	36.38326	E	2000m	11/8/2019
466	*Crassula volkensii* Engl.	Kenya	Kajiado	1.27248	S	36.38326	E	2000m	11/8/2019
467	*Cotyledon barbeyi*	Kenya	Kajiado	1.27248	S	36.38326		2000m	11/8/2019
468	*Kleinia squarrosa*	Kenya	Kajiado	1.27248	S	36.38326	E	2000m	11/8/2019
469	*Chlorophytum macrophyllum*	Kenya	Kajiado	1.27248	S	36.38326	E	2000m	11/8/2019
470	*Euphobia* sp	Kenya	Kajiado	0.221749	S	37.53356	E	1000m	11/8/2019
472	*K.* cf *citrina*	Kenya	Machakos	1.45215	S	36.49455	E	1728m	12/8/2019
473	Hyacinthaceae	Kenya	Machakos	1.4277	S	36.30467	E	1674m	12/8/2019
474	*K. glaucescens*	Kenya	Machakos	1.4309	S	36.50233	E	1691m	12/8/2019
475	*K. glaucescens*	Kenya	Machakos	1.28504	S	37.04118	E	1822m	12/8/2019
476	*K. laciniata*	Kenya	Machakos	1.28059	S	37.04345	E	1747m	12/8/2019
580	*K. lanceolata*	Kenya	Machakos	1.28059	S	37.04345	E	1747m	12/8/2019
477	*Crassula* sp	Kenya	Machakos	1.28504	S	37.04118	E	1822m	19/01/2019
478	*K. laciniata*	Kenya	Machakos	1.28504	S	37.04118	E	1822m	12/8/2019
479	*K. lanceolata*	Kenya	Machakos	1.28504	S	37.04118	E	1822m	12/8/2019
480	*K. densiflora*	Kenya	Machakos	1.26135	S	37.12348	E	2060m	13/08/2019
481	*K. lanceolata*	Kenya	Machakos	1.26109	S	37.12219	E	2077m	13/08/2019
482	*K. densiflora*	Kenya	Machakos	1.26109	S	37.12219	E	2077m	13/08/2019
483	*K. lanceolata*	Kenya	Machakos	1.25387	S	37.11244	E	1870m	13/08/2019
484	*K. lanceolata*	Kenya	Machakos	1.06389	S	37.1797	E	1370m	13/08/2019
485	*K. densiflora*	Kenya	Machakos	1.07317	S	37.15218	E	2140m	15/08/2019
489	*K. lanceolata*	Kenya	Kiambu	1.1285	S	37.0486	E	1447m	17/01/2019
494	*K. lanceolata*	Kenya	Kiambu	0.44172	S	36.27104	E	2015m	15/08/2019
495	*K. lanceolata*	Kenya	Naivasha	0.48121	S	36.24505	E	1917m	15/08/2019

496	*K. densiflora*	Kenya	Naivasha	0.48123	S	36.2435	E	1918m	15/08/2019
497	*K. glaucescens*	Kenya	Naivasha	0.501	S	36.21516	E	1899m	15/08/2019
497A	*K. glaucescens*	Kenya	Naivasha	0.501	S	36.21516	E	1899m	15/08/2019
498	*K. lanceolata*	Kenya	Naivasha	0.501	S	36.21576	E	1649m	15/08/2019
502	*K. glaucescens*	Kenya	Narok	1.05246	S	35.57153	E	1850m	15/08/2019

GeoCAT Data

CatalogNumber	Country	Year	Dec_Lat	Dec_Long	Occurrence Details	scientificname
K000332870	Kenya	1992-12-08T00:00	-3.75	39.7	https://gbif.org/occurrence/912288152	*kalanchoe ballyi*
K000332873	Kenya	1990-08-02T00:00	-3.96667	38.95	https://gbif.org/occurrence/912288150	*kalanchoe ballyi*
102250328	Kenya	8/2/1990	-3.96667	38.95	https://gbif.org/occurrence/4061552280	*kalanchoe ballyi*
102250329	Kenya	8/2/1990	-3.96667	38.95	https://gbif.org/occurrence/4031701618	*kalanchoe ballyi*
2980792	Kenya	8/2/1990	-3.96667	38.95	https://gbif.org/occurrence/1260350127	*kalanchoe ballyi*
K000332872	Kenya	1989-02-	-	39.73333	https://gbif.org/occurrence/912288175	*kalanchoe ballyi*

		21T00:00	3.06667			
2980793	Kenya	2/21/1989	-3.66666	39.73333	https://gbif.org/occurrence/1260350151	*kalanchoe ballyi*
K000332869	Kenya	1988-02-21T00:00	-3.45	39.73333	https://gbif.org/occurrence/912288134	*kalanchoe ballyi*
K000332871	Kenya	1982-12-25T00:00	-4.16667	39.16667	https://gbif.org/occurrence/912288146	*kalanchoe ballyi*
B 10 1185086	Kenya	2/16/1977	-3.73333	39.7	https://gbif.org/occurrence/2805020834	*kalanchoe ballyi*
S09-37514	Tanzania	11/14/1999	-4.27	37.93	https://gbif.org/occurrence/1096699571	*kalanchoe crenata*
101209576	Tanzania	9/24/2000	-7.78333	36.53333	https://gbif.org/occurrence/2819337320	*kalanchoe crenata*
S12-29070	Tanzania	11/20/1999	-4.27	37.92	https://gbif.org/occurrence/1096797039	*kalanchoe crenata*
103152825	Tanzania	9/24/2000	-7.78333	36.53333	https://gbif.org/occurrence/4061383464	*kalanchoe crenata*
103152827	Tanzania	9/24/2000	-7.78333	36.53333	https://gbif.org/occurrence/4062056781	*kalanchoe crenata*

103152828	Tanzania	9/24/2000	-7.78333	36.53333	https://gbif.org/occurrence/4031940171	*kalanchoe crenata*
103152997	Kenya	11/19/1989	-0.96667	38.95	https://gbif.org/occurrence/4061350639	*kalanchoe glaucescens*
103152998	Kenya	11/19/1989	-0.96667	38.95	https://gbif.org/occurrence/4031918006	*kalanchoe glaucescens*
WAG.1211660	Kenya	2/8/1985	-1.26667	36.58333	https://gbif.org/occurrence/2517486116	*kalanchoe glaucescens*
WAG.1212074	Kenya	12/18/1981	-3.62333	39.85361	https://gbif.org/occurrence/2515924085	*kalanchoe glaucescens*
101210361	Kenya	1/7/1980	-3.63333	39.53333	https://gbif.org/occurrence/2824357307	*kalanchoe glaucescens*
	Kenya	6/30/2019	-0.56972	37.15778	https://gbif.org/occurrence/2397826306	*kalanchoe densiflora*
	Kenya	6/30/2019	-0.67694	37.10806	https://gbif.org/occurrence/2397827014	*kalanchoe densiflora*
	Kenya	6/30/2019	-0.49833	36.94111	https://gbif.org/occurrence/2397827197	*kalanchoe densiflora*
	Kenya	6/29/2019	-0.49586	36.80864	https://gbif.org/occurrence/2397827541	*kalanchoe densiflora*

	Kenya	6/28/2019	-0.36158	37.06689	https://gbif.org/occurrence/2397828319	*kalanchoe densiflora*
	Kenya	7/2/2019	-0.69806	36.82328	https://gbif.org/occurrence/2397827594	*kalanchoe densiflora*
	Kenya	7/2/2019	-0.675	36.8095	https://gbif.org/occurrence/2397828805	*kalanchoe densiflora*
30932270	Colombia	8/11/2019	4.662569	-74.3514	https://gbif.org/occurrence/3079515653	*kalanchoe densiflora*
49201758	Kenya	2019-08-10T17:58:04	-0.78131	36.26527	https://gbif.org/occurrence/2641394633	*kalanchoe densiflora*
33226449	Ecuador	2019-09-22T11:47:33	-2.91513	-79.0104	https://gbif.org/occurrence/2626141587	*kalanchoe densiflora*
101210400	Tanzania	5/25/2006	-5.81667	34.31667	https://gbif.org/occurrence/2824339307	*kalanchoe laciniata*
1714837	Tanzania	11/24/2001	-8.61194	35.62083	https://gbif.org/occurrence/1258957043	*kalanchoe laciniata*
B 10 0216347	Yemen	4/9/1997	15.48333	43.53333	https://gbif.org/occurrence/911792406	*kalanchoe laciniata*
B 10	Yemen	4/9/1997	15.4833	43.36667	https://gbif.org/occurrence/911792414	*kalanchoe laciniata*

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WAG.1212086	Cameroon	11/18/1996	6.25	10.43333	https://gbif.org/occurrence/2517441232	*kalanchoe laciniata*
L.Ellemann449	Tanzania	4/27/1993	-3.116	35.2	https://gbif.org/occurrence/47792375	*kalanchoe laciniata*
62274	United States of America	10/22/1992	33.3	-118.317	https://gbif.org/occurrence/1261338871	*kalanchoe laciniata*
13206	Mexico	3/30/1990	18.4943	-88.3929	https://gbif.org/occurrence/1894690742	*kalanchoe laciniata*
MW0586895	Ethiopia	12/19/1990	5.083333	39.95	https://gbif.org/occurrence/1697710611	*kalanchoe laciniata*
101209501	Uganda	8/23/1982	0.366667	30.46667	https://gbif.org/occurrence/2819309321	*kalanchoe laciniata*
1164	Nigeria	8/8/1981	4.979599	8.337359	https://gbif.org/occurrence/3460374340	*kalanchoe laciniata*
2980795	Kenya	1/10/1996	-3.11666	39.85	https://gbif.org/occurrence/4061763004	*kalanchoe lateritia*
62452	Congo	2/19/1994	1.432778	28.50222	https://gbif.org/occurrence/1261340787	*kalanchoe lateritia*

101211816	Kenya	7/23/1993	-3.96667	38.95	https://gbif.org/occurrence/2824353335	*kalanchoe lateritia*
103153384	Kenya	7/23/1993	-3.96667	38.95	https://gbif.org/occurrence/4061857769	*kalanchoe lateritia*
62229	Tanzania	1992-03	-4.76667	39.11667	https://gbif.org/occurrence/1261338399	*kalanchoe lateritia*
62174	Tanzania	8/9/1991	-5.53333	38.63333	https://gbif.org/occurrence/1261337804	*kalanchoe lateritia*
2980796	Kenya	5/22/1990	-3.91666	39.58333	https://gbif.org/occurrence/1260350175	*kalanchoe lateritia*
101211424	Kenya	9/18/1990	-3.73333	39.13333	https://gbif.org/occurrence/2824336327	*kalanchoe lateritia*
103153249	Kenya	9/18/1990	-3.73333	39.13333	https://gbif.org/occurrence/4061875803	*kalanchoe lateritia*
103153250	Kenya	9/18/1990	-3.73333	39.13333	https://gbif.org/occurrence/4032005860	*kalanchoe lateritia*
102134631	Kenya	7/9/1989	-4.1	39.45	https://gbif.org/occurrence/4061520476	*kalanchoe lateritia*
102134632	Kenya	7/9/1989	-4.1	39.45	https://gbif.org/occurrence/4031964620	*kalanchoe lateritia*
2512989	Kenya	7/9/1989	-4.1	39.45	https://gbif.org/occurrence/1259834705	*kalanchoe lateritia*

62405	Malawi	6/27/1987	-16.0167	34.78333	https://gbif.org/occurrence/1261340288	*kalanchoe lateritia*
101211421	Kenya	7/13/1987	-3.25	39.71667	https://gbif.org/occurrence/2824322328	*kalanchoe lateritia*
103153247	Kenya	7/13/1987	-3.25	39.71667	https://gbif.org/occurrence/4062061579	*kalanchoe lateritia*
103153248	Kenya	7/13/1987	-3.25	39.71667	https://gbif.org/occurrence/4032169147	*kalanchoe lateritia*
WAG.1212149	Kenya	5/18/1985	-3.4	38.4	https://gbif.org/occurrence/2517758198	*kalanchoe lateritia*
95712	Portugal	6/3/1985	40.20509	-8.42248	https://gbif.org/occurrence/4867488475	*kalanchoe lateritia*
103289644	Kenya	1959-01	1.8	37.1	https://gbif.org/occurrence/4061368003	*kalanchoe marmorata*
PRE0759428-0	Ethiopia	10/9/1959	7.333333	38.7	https://gbif.org/occurrence/3708349913	*kalanchoe marmorata*
54144	Portugal	5/17/1956	40.20509	-8.42248	https://gbif.org/occurrence/4867493221	*kalanchoe marmorata*
103289645	Tanzania	1956-07	-2.05	35.61667	https://gbif.org/occurrence/4062228596	*kalanchoe marmorata*
103289642	Kenya	1952-09	0.7	38.01667	https://gbif.org/occurrence/4061422760	*kalanchoe marmorata*
BR000001538029 6	Burundi	1950-03	-3.11667	29.26667	https://gbif.org/occurrence/1840038088	*kalanchoe marmorata*

103289647	Uganda	1938-06	0.05	30.4	https://gbif.org/occurrence/4062130071	*kalanchoe marmorata*
103289648	Uganda	1938-12	-0.33333	30.1	https://gbif.org/occurrence/4061944021	*kalanchoe marmorata*
BR000000888 6774	Congo	1937-12	-1.18333	29.45	https://gbif.org/occurrence/1839528645	*kalanchoe marmorata*
103289646	Uganda	1934-02	0.333333	32.66667	https://gbif.org/occurrence/4061407206	*kalanchoe marmorata*
103289643	Kenya	1933-06	-1.41667	36.63333	https://gbif.org/occurrence/4062128273	*kalanchoe marmorata*
	Kenya	11/18/1973	-0.7833	37.65	https://gbif.org/occurrence/3017828479	*kalanchoe mitejea*
2980801	Kenya	12/9/1995	-3.98333	39.51666	https://gbif.org/occurrence/4061621535	*kalanchoe obtusa*
2980808	Kenya	2/28/1994	-4.13333	39.46666	https://gbif.org/occurrence/4061781200	*kalanchoe obtusa*
2980805	Kenya	8/16/1991	-4.13333	39.46666	https://gbif.org/occurrence/1260350155	*kalanchoe obtusa*
102250334	Kenya	5/17/1990	-3.98333	39.53333	https://gbif.org/occurrence/4062198485	*kalanchoe obtusa*

2980807	Kenya	5/17/1990	-3.98333	39.53333	https://gbif.org/occurrence/1260350165	*kalanchoe obtusa*
102250336	Kenya	11/24/1990	-3.03333	39.8	https://gbif.org/occurrence/4062097480	*kalanchoe obtusa*
2980801	Kenya	12/9/1995	-3.98333	39.51666	https://gbif.org/occurrence/4061621535	*kalanchoe obtusa*
2980808	Kenya	2/28/1994	-4.13333	39.46666	https://gbif.org/occurrence/4061781200	*kalanchoe obtusa*
2980802	Kenya	7/19/1986	-4.1	39.45	https://gbif.org/occurrence/1260350139	*kalanchoe obtusa*
2980805	Kenya	8/16/1991	-4.13333	39.46666	https://gbif.org/occurrence/1260350155	*kalanchoe obtusa*
2853593	Tanzania	10/11/1972	-7	37.8	https://gbif.org/occurrence/1260209931	*kalanchoe obtusa*
102250334	Kenya	5/17/1990	-3.98333	39.53333	https://gbif.org/occurrence/4062198485	*kalanchoe obtusa*
2980807	Kenya	5/17/1990	-3.98333	39.53333	https://gbif.org/occurrence/1260350165	*kalanchoe obtusa*
2980800	Kenya	6/2/1998	-3.83333	38.66666	https://gbif.org/occurrence/4061618566	*kalanchoe nyikae*

2980798	Kenya	3/29/1990	-3.23333	39.71666	https://gbif.org/occurrence/1260350135	*kalanchoe nyikae*
102250330	Kenya	12/1/1990	-2.88333	39.65	https://gbif.org/occurrence/4062195389	*kalanchoe nyikae*
2980799	Kenya	12/1/1990	-2.88333	39.65	https://gbif.org/occurrence/1260350168	*kalanchoe nyikae*
2980797	Kenya	11/17/1989	-3.96666	38.95	https://gbif.org/occurrence/1260350161	*kalanchoe nyikae*
3017755	Kenya	1970-05	-3.63333	38.73333	https://gbif.org/occurrence/4061763190	*kalanchoe nyikae*
3017758	Kenya	1969-08	-3.38333	38.58333	https://gbif.org/occurrence/4061050850	*kalanchoe nyikae*
3017756	Tanzania	1957-07	-3.68333	37.65	https://gbif.org/occurrence/4061075103	*kalanchoe nyikae*
3017757	Tanzania	1945-01	-4.06666	37.73333	https://gbif.org/occurrence/4062117838	*kalanchoe nyikae*
3017753	Kenya	1945-07	-3.25	39.71666	https://gbif.org/occurrence/4061093435	*kalanchoe nyikae*
3017754	Tanzania	1943-06	-4.63333	38.06666	https://gbif.org/occurrence/4061066265	*kalanchoe nyikae*

2535304	Tanzania		-4.85	38.68333	https://gbif.org/occurrence/1259859331	*kalanchoe nyikae*
WAG.1212164	Ethiopia	1/2/1969	9.616667	42.73333	https://gbif.org/occurrence/2517701165	*kalanchoe lugardii*
WAG.1212165	Ethiopia	1/2/1969	9.616667	42.73333	https://gbif.org/occurrence/2517707160	*kalanchoe lugardii*
101211509	Ethiopia	1/2/1967	9.616667	41.78333	https://gbif.org/occurrence/2824335329	*kalanchoe lugardii*
K000232735	Kenya	1978-09-01T00:00	1.716667	37.28333	https://gbif.org/occurrence/912208811	*kalanchoe ndotoensis*

Appendix 7: Data Matrix Used in Morphological Analysis

LL	LW	LBL	LPL	LPW	IL	FN	FLL	PL	CLL	CAL	CTLL	CBW	CCB	CL	CTL	CTW	CD	COL	CLW	PN	STNO	FLL	FLS	SCT	AL	PFJL	PFJS	EAE	AW	AGL	AGW	STYL	CAL	CAW	SL	SS	PP	IP	FT	FLL	SF	SPA	PF	PC	CS	LAR	LA	LOC	SA	CF	SYS	LSH	LP	SP
79.200	20.400	?	?	?	?	0.000	180.000	5.000	2.700	?	?	?	4.000	12.300	?	?	5.800	5.200	1.000	4.000	80.000	6.500	?	?	0.17	?	?	?	?	?	?	2.90	?	?	0.800	0.200	?	?	1	1	3	1	1	1	0	0	0	0	0	0	0	0	0
54.000	22.600	?	?	?	231.000	?	14.000	2.811	4.107	?	?	?	4.000	?	?	?	2.500	11.775	?	4.000	80.000	5.580	?	80.00	0.53	?	?	?	?	?	?	3.43	35.300	1.30	0.600	0.200	?	?	1	1	3	1	1	?	0	0	0	0	0	0	0	0	0	0
170.000	80.000	130.000	40.000	2.000	120.000	1.000	22.000	2.000	4.550	3.85	0.700	2.000	0.700	80.000	5.000	3.35	3.550	3.200	1.40	4.000	80.000	?	?	?	?	?	?	?	?	?	?	?	?	?	0.555	0.200	0	0	0	1	1	1	0	1	6	0	0	0	0	0	1	0	0	0	0
65	35	49	16	2.	11	0.	18	2.	4.	3.	0.	1.	0.	15	7.	2.	2.	5.	2.	4.	8.	7.	6.	8.	0.	6.	5.	1.	0.	?	?	1.	5.	1.	0.	0.	0	0	1	1	1	1	1	2	0	0	0	0	0	1	0	0	0	0

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Appendix 8: List of Specimens Used in Molecular Work.

Sample Name	Description	Organism	Total Yield (Reads)	Q30 Percentage	Well Position (plates only)	State (fresh, degraded)	Medium (H2O, 1X TE, EB etc)	Volume* (µL)	Concentr. (ng/µL)	Quant method (Qubit, etc)	UV 260:280 ratio	Group ID
7011-JK-1_002	TL02_TR23-01	*K.* sp. A (FTEA)	1,157,491	66.63	A2	Degraded	EB (E.Z.N.A. mini-plant kit)	100	2.12	Qubit	0.91	1
7011-JK-1_003	TL02_TR23-09	*K. humilis*	1,569,059	82.85	A3	Degraded	EB (E.Z.N.A. mini-plant kit)	46	4.26	Qubit	0.78	1
7011-JK-1_004	TL02_TR25-02	*K. nyikae* subsp. *auriculata*	3,436,904	86.10	A4	Degraded	EB (E.Z.N.A. mini-plant kit)	48	4.6	Qubit	0.75	1
7011-JK-1_005	TL02_TRF-11	*K. leblanciae*	3,514,456	86.97	A5	Degraded	EB (E.Z.N.A. mini-plant kit)	48	3.14	Qubit	0.46	1
7011-JK-1_006	TL02_TR25-06	*K. nyikae* subsp. *nyikae* (isotype)	5,310,128	85.99	A6	Degraded	EB (E.Z.N.A. mini-plant kit)	45	2.3	Qubit	0.44	1
7011-JK-1_007	TL02_TR25-07	*K.* lateritia var. *prostrata*	7,753,373	87.57	A7	Degraded	EB (E.Z.N.A. mini-plant kit)	48	2.3	Qubit	0.69	1
7011-JK-1_008	TL02_TR25-09	*K. lateritia* var. *prostrata* (isotype)	18,463,114	91.99	A8	Degraded	EB (E.Z.N.A. mini-plant kit)	95	2.56	Qubit	0.59	1
7011-JK-1_009	TL02_TR15-12	*K. alticola*	4,067,557	85.37	B1	Degraded	EB (E.Z.N.A. mini-plant kit)	41	9.62	Qubit	0.88	2
7011-JK-1_010	TL02_TR22-09	*K. campanulata*	8,760,853	89.64	B2	Degraded	EB (E.Z.N.A. mini-plant kit)	38	13.6	Qubit	1.38	2
7011-JK-1_011	TL02_TR23-02	*K.* sp B (FTEA)	202,354	86.86	B3	Degraded	EB (E.Z.N.A. mini-plant kit)	43	11.4	Qubit	0.44	2
7011-JK-	TL02_TR	*K. nyikae* subsp. *nyikae*	5,954,839	88.52	B4	Degra	EB (E.Z.N.A.	48	7.32	Qubi	0.51	2

1_012	25-04					ded	mini-plant kit)			t		
7011-JK-1_013	TL02_TR25-11	*K. lateritia* var. *lateritia*	567,698	73.59	B5	Degraded	EB (E.Z.N.A. mini-plant kit)	48	7.25	Qubit	0.69	2
7011-JK-1_014	TL02_TR25-12	*K. lateritia* var. *lateritia*	13,041,633	90.50	B6	Degraded	EB (E.Z.N.A. mini-plant kit)	48	8.14	Qubit	0.71	2
7011-JK-1_015	TL02_TR25-13	*K. lateritia* var. *lateritia*	4,743,744	90.31	B7	Degraded	EB (E.Z.N.A. mini-plant kit)	48	11	Qubit	1.04	2
7011-JK-1_016	TL02_TR25-05	*K. nyikae* subsp. *nyikae*	4,744,482	85.40	B8	Degraded	EB (E.Z.N.A. mini-plant kit)	48	6.52	Qubit	0.83	2
7011-JK-1_017	TL02_GE03-13	*K. nyikae* subsp. *auriculata*	9,400,126	88.14	C1	Degraded	EB (E.Z.N.A. mini-plant kit)	94	7.5	Qubit	0.65	3
7011-JK-1_018	TL02_TR13-06	*K. blossfeldiana*	5,098,798	86.27	C2	Degraded	EB (E.Z.N.A. mini-plant kit)	41	13.7	Qubit	0.84	3
7011-JK-1_019	TL02_TR14-08	*K. paniculata*	22,991,318	90.47	C3	Degraded	EB (E.Z.N.A. mini-plant kit)	41	15.7	Qubit	1.33	3
7011-JK-1_020	TL02_TR21-09	*K. daigremontiana*	12,497,522	89.96	C4	Degraded	EB (E.Z.N.A. mini-plant kit)	31	19.1	Qubit	2.04	3
7011-JK-1_021	TL02_TR23-12	*K. pinnata*	3,306,085	84.77	C5	Degraded	EB (E.Z.N.A. mini-plant kit)	46	13.1	Qubit	0.93	3
7011-JK-1_022	TL02_TR25-03	*K. nyikae* subsp. *auriculata* (isotype)	2,788,238	86.87	C6	Degraded	EB (E.Z.N.A. mini-plant kit)	48	14.9	Qubit	0.6	3
7011-JK-1_023	TL02_TR25-10	*K. lateritia* var. *prostrata*	1,849,216	76.51	C7	Degraded	EB (E.Z.N.A. mini-plant kit)	48	13.6	Qubit	0.81	3
7011-JK-1_024	TL02_TRF-04	*K. brachyloba*	4,485,519	87.57	C8	Degraded	EB (E.Z.N.A. mini-plant kit)	124	5.01	Qubit	0.45	3
7011-JK-1_025	TL02_TRF-08	*K. integrifolia*	630,804	85.26	C9	Degraded	EB (E.Z.N.A. mini-plant kit)	124	5.44	Qubit	0.59	3
7011-JK-1_026	TL02_TRF-16	*K. thyrsiflora*	2,869,127	86.43	C10	Degraded	EB (E.Z.N.A. mini-plant kit)	79	8.23	Qubit	0.69	3

7011-JK-1_027	TL02_GE03-14	*K. lateritia* var. *pseudolateritia*	8,354,053	86.35	D1	Degraded	EB (E.Z.N.A. mini-plant kit)	94	13.1	Qubit	0.83	4
7011-JK-1_028	TL02_TR16-13	*K. welwitschii*	316,049	82.56	D2	Degraded	EB (E.Z.N.A. mini-plant kit)	41	24.1	Qubit	0.47	4
7011-JK-1_029	TL02_TR20-01	*K. luciae*	10,437,065	89.35	D3	Degraded	EB (E.Z.N.A. mini-plant kit)	31	24.4	Qubit	0.93	4
7011-JK-1_030	TL02_TR20-03	*K. neglecta*	1,934,149	88.63	D4	Degraded	EB (E.Z.N.A. mini-plant kit)	31	31.5	Qubit	1.51	4
7011-JK-1_031	TL02_TR23-08	*K. usambarensis*	1,573,042	82.10	D5	Degraded	EB (E.Z.N.A. mini-plant kit)	46	21.3	Qubit	0.96	4
7011-JK-1_032	TL02_TR23-11	*K. peteri*	9,791,687	88.73	D6	Degraded	EB (E.Z.N.A. mini-plant kit)	46	29.5	Qubit	1.01	4
7011-JK-1_033	TL02_TR25-01	*K. nyikae* subsp. *auriculata*	6,380,891	85.80	D7	Degraded	EB (E.Z.N.A. mini-plant kit)	48	17.1	Qubit	0.8	4
7011-JK-1_034	TL02_TR25-08	*K. laterita* var. *pseudolateritia* (isotype)	8,893,310	86.81	D8	Degraded	EB (E.Z.N.A. mini-plant kit)	48	16.2	Qubit	0.71	4
7011-JK-1_035	TL02_TR09-11	*K. crundallii*	9,374,840	89.27	D9	Degraded	EB (E.Z.N.A. mini-plant kit)	36	30	Qubit	0.61	4
7011-JK-1_036	TL02_TRF-12	*K. longiflora*	2,423,852	87.54	D10	Degraded	EB (E.Z.N.A. mini-plant kit)	81	15.9	Qubit	1.12	4
7011-JK-1_037	TL02_GE03-19	*K. aubrevillei*	2,064,709	83.97	E1	Degraded	EB (E.Z.N.A. mini-plant kit)	44	27.4	Qubit	0.92	5
7011-JK-1_038	TL02_TR14-09	*K. quartiniana*	4,807,973	91.03	E2	Degraded	EB (E.Z.N.A. mini-plant kit)	41	35.6	Qubit	0.76	5
7011-JK-1_039	TL02_TR18-10	*K. deficiens*	4,192,243	90.19	E3	Degraded	EB (E.Z.N.A. mini-plant kit)	76	36.3	Qubit	0.96	5
7011-JK-1_040	TL02_TR21-07	*K. petitiana*	7,700,928	90.69	E4	Degraded	EB (E.Z.N.A. mini-plant kit)	39	38.1	Qubit	1.06	5
7011-JK-	TL02_TR	*K. prolifera*	4,982,502	91.00	E5	Degra	EB (E.Z.N.A.	39	27.1	Qubi	1.32	5

1_041	22-05					ded	mini-plant kit)			t		
7011-JK-1_042	TL02_TR23-06	*K. boranae*	3,184,892	88.35	E6	Degraded	EB (E.Z.N.A. mini-plant kit)	43	28.1	Qubit	0.82	5
7011-JK-1_043	TL02_TR23-10	*K. germanae*	494,439	84.87	E7	Degraded	EB (E.Z.N.A. mini-plant kit)	46	14.2	Qubit	0.66	5
7011-JK-1_044	TL02_TR09-08	*K. latisepala*	5,493,468	90.43	E8	Degraded	EB (E.Z.N.A. mini-plant kit)	36	38.9	Qubit	1.04	5
7011-JK-1_045	TL02_TRF-06	*K. elizae*	5,468,380	90.72	E9	Degraded	EB (E.Z.N.A. mini-plant kit)	81	26.6	Qubit	1.6	5
7011-JK-1_046	TL02_TRF-13	*K. stenosiphon*	3,732,703	90.13	E10	Degraded	EB (E.Z.N.A. mini-plant kit)	81	22.4	Qubit	0.8	5
7011-JK-1_047	TL02_TR10-08	*K. lateritia* cf. *prostrata*	4,018,134	90.23	F1	Degraded	EB (E.Z.N.A. mini-plant kit)	41	10.3	Qubit	0.95	6
7011-JK-1_048	TL02_TR10-11	*K. lateritia* cf. *lateritia*	4,352,724	90.41	F2	Degraded	EB (E.Z.N.A. mini-plant kit)	41	19.8	Qubit	1.04	6
7011-JK-1_049	TL02_TR12-07	*K. lateritia*	4,002,373	90.48	F3	Degraded	EB (E.Z.N.A. mini-plant kit)	41	24.6	Qubit	1.33	6
7011-JK-1_050	TL02_TR14-03	*K. hametiorum*	11,445,608	91.22	F4	Degraded	EB (E.Z.N.A. mini-plant kit)	41	22.7	Qubit	1.14	6
7011-JK-1_051	TL02_TR15-01	*K. linearifolia*	3,472,586	90.92	F5	Degraded	EB (E.Z.N.A. mini-plant kit)	41	23.1	Qubit	1.3	6
7011-JK-1_052	TL02_TR16-04	*K. delagoensis*	3,563,906	90.78	F6	Degraded	EB (E.Z.N.A. mini-plant kit)	41	14.7	Qubit	1.31	6
7011-JK-1_053	TL02_TR16-11	*K. yemensis*	6,381,450	90.91	F7	Degraded	EB (E.Z.N.A. mini-plant kit)	41	17.2	Qubit	0.99	6
7011-JK-1_054	TL02_TR17-05	*K.* sp	4,478,751	90.56	F9	Degraded	EB (E.Z.N.A. mini-plant kit)	41	30.3	Qubit	1.32	6
7011-JK-1_055	TL02_TR23-05	*K. bipartita*	4,939,408	90.97	F10	Degraded	EB (E.Z.N.A. mini-plant kit)	43	31.6	Qubit	0.63	6

7011-JK-1_056	TL02_TR09-07	*K. sexangularis*	416,602	61.30	F11	Degraded	EB (E.Z.N.A. mini-plant kit)	36	27.9	Qubit	0.88	6
7011-JK-1_057	TL02_TR10-06	*K. lanceolata*	4,364,720	91.08	G1	Degraded	EB (E.Z.N.A. mini-plant kit)	41	37.4	Qubit	1.71	7
7011-JK-1_058	TL02_TR12-01	*K. crenata*	5,858,235	90.13	G2	Degraded	EB (E.Z.N.A. mini-plant kit)	41	32.6	Qubit	1.82	7
7011-JK-1_059	TL02_TR12-02	*K. nyikae* subsp. *nyikae*	6,748,444	90.49	G3	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33	Qubit	1.96	7
7011-JK-1_060	TL02_TR12-08	*K. lateritia* cf. *lateritia*	5,468,056	89.98	G4	Degraded	EB (E.Z.N.A. mini-plant kit)	41	30.5	Qubit	1.61	7
7011-JK-1_061	TL02_TR12-09	*K. lateritia* var. *pseudolateritia*	5,383,231	90.22	G5	Degraded	EB (E.Z.N.A. mini-plant kit)	41	37.9	Qubit	1.78	7
7011-JK-1_062	TL02_TR12-10	*K. lateritia* cf. *prostrata*	7,360,964	90.87	G6	Degraded	EB (E.Z.N.A. mini-plant kit)	41	27.1	Qubit	1.8	7
7011-JK-1_063	TL02_TR17-02	*K.* sp	5,201,556	90.43	G7	Degraded	EB (E.Z.N.A. mini-plant kit)	41	23.6	Qubit	1.83	7
7011-JK-1_064	TL02_TR17-03	*K.* sp	3,411,638	88.90	G8	Degraded	EB (E.Z.N.A. mini-plant kit)	41	32.8	Qubit	1.93	7
7011-JK-1_065	TL02_TR17-06	*K.* sp	4,331,165	90.43	G9	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33.8	Qubit	1.97	7
7011-JK-1_066	TL02_TR17-07	*K.* sp.	3,454,307	90.32	G10	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33.2	Qubit	1.94	7
7011-JK-1_067	TL02_TR17-11	*K. lateritia* var. *pseudolateritia*	4,084,562	90.53	G11	Degraded	EB (E.Z.N.A. mini-plant kit)	41	26.5	Qubit	1.93	7
7011-JK-1_068	TL02_TR17-12	*K. lateritia* var. *prostrata*	4,332,901	90.26	G12	Degraded	EB (E.Z.N.A. mini-plant kit)	41	25.6	Qubit	1.72	7
7011-JK-1_069	TL02_GE03-25	*K. ballyi*	4,786,713	89.74	H1	Degraded	EB (E.Z.N.A. mini-plant kit)	36	47.2	Qubit	1.79	8
7011-JK-	TL02_TR	*K. citrina*	4,468,779	89.73	H2	Degra	EB (E.Z.N.A.	41	44.4	Qubi	1.71	8

1_070	10-02					ded	mini-plant kit)			t		
7011-JK-1_071	TL02_TR 10-04	*K. obtusa*	4,954,448	89.93	H3	Degraded	EB (E.Z.N.A. mini-plant kit)	41	39.2	Qubit	1.54	8
7011-JK-1_072	TL02_TR 08-10	*K.* sp.(*nyikae*)	4,490,945	90.34	H4	Degraded	EB (E.Z.N.A. mini-plant kit)	51	37.9	Qubit	1.64	8
7011-JK-1_073	TL02_TR 12-11	*Cotyledon barbeyi*	4,746,170	90.56	H5	Degraded	EB (E.Z.N.A. mini-plant kit)	41	38.9	Qubit	1.87	8
7011-JK-1_074	TL02_TR 17-10	*K. lateritia* var. *lateritia* /*aubrevillei*	4,439,816	89.79	H6	Degraded	EB (E.Z.N.A. mini-plant kit)	41	42.4	Qubit	2.1	8
7011-JK-1_075	TL02_TR 27-01	*K. marmorata*	5,284,688	90.04	H7	Degraded	EB (E.Z.N.A. mini-plant kit)	48	44.4	Qubit	1.86	8
7011-JK-1_076	TL02_TR 08-02	*K. glaucescens*	3,834,172	89.77	H8	Degraded	EB (E.Z.N.A. mini-plant kit)	51	54	Qubit	1.87	8
7011-JK-1_077	TL02_TR 08-04	*K. densiflora* var. *densiflora*	4,037,039	90.37	H9	Degraded	EB (E.Z.N.A. mini-plant kit)	51	48.1	Qubit	2.22	8
7011-JK-1_078	TL02_TR 08-05	*K. laciniata*	3,471,605	89.66	H10	Degraded	EB (E.Z.N.A. mini-plant kit)	51	37.7	Qubit	1.94	8
7011-JK-1_079	TL02_TR 08-09	*Kmetija*	3,489,612	90.09	H11	Degraded	EB (E.Z.N.A. mini-plant kit)	51	39.8	Qubit	2.13	8
7011-JK-1_080	TL02_TR 08-11	*K. prittwitzii*	4,450,219	90.30	H12	Degraded	EB (E.Z.N.A. mini-plant kit)	51	42.8	Qubit	2.01	8

Arbor Biosciences myReads® Project Sample Submission – DNA

COMPLETE form in areas near yellow cells to the best of your knowledge
EMAIL this completed form to service@arborbiosci.com prior to shipment
FOLLOW the instructions given in the Sample Preparation Guide
INCLUDE a signed and dated print copy of this form with your shipment *(scale sheet to ~70% for printing)*
NEVER ship irreplaceable materials

v190829

SAMPLE INFORMATION

CLIENT NAME	**Tori K. R. Johansen**		**NOTES**
CLIENT INSTITUTION	**NHM, University of Oslo**		
NUMBER OF SAMPLES	**80**		Group 5+6 should be divided into two new groups based on your expertice.
QUOTE NUMBER			All groups can be changed/adjusted if required for better sequencing results.
myReads PROJECT ID	**GT_NHM_21**		
FORM FILL DATE	**5/13/2020**		

gDNA information

Sample ID	Tube Label	Well Position (plates only)	Organism	State (fresh, degraded)	Medium (H2O, 1X TE, EB etc)	Volume* (µL)	Concentr. (ng/µL)	Quant method (Qubit, etc)	UV 260:280 ratio	Group ID
GE03-15		A1	*K. nyikae* subsp. *nyikae*	Degraded	EB (E.Z.N.A. mini-plant kit)	94	1.51	Qubit	0.76	1
TR23		A2	*K.* sp. *A (FTEA)*	Degr	EB (E.Z.N.A.	100	2.12	Qubit	0.91	1

-01				aded	mini-plant kit)					
TR23-09		A3	*K. humilis*	Degraded	EB (E.Z.N.A. mini-plant kit)	46	4.26	Qubit	0.78	1
TR25-02		A4	*K. nyikae* subsp. *auriculata*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	4.6	Qubit	0.75	1
TRF-11		A5	*K. leblanciae*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	3.14	Qubit	0.46	1
TR25-06		A6	*K. nyikae subsp. nyikae* (isotype)	Degraded	EB (E.Z.N.A. mini-plant kit)	45	2.3	Qubit	0.44	1
TR25-07		A7	*K. lateritia* var. *prostrata*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	2.3	Qubit	0.69	1
TR25-09		A8	*K. lateritia* var. *prostrata* (isotype)	Degraded	EB (E.Z.N.A. mini-plant kit)	95	2.56	Qubit	0.59	1
TR15-12		B1	*K. alticola*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	9.62	Qubit	0.88	2
TR22-09		B2	*K. campanulata*	Degraded	EB (E.Z.N.A. mini-plant kit)	38	13.6	Qubit	1.38	2
TR23-02		B3	*K.* sp *B (FTEA)*	Degraded	EB (E.Z.N.A. mini-plant kit)	43	11.4	Qubit	0.44	2
TR25-04		B4	*K. nyikae* subsp. *nyikae*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	7.32	Qubit	0.51	2
TR25-11		B5	*K. lateritia* var. *lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	7.25	Qubit	0.69	2
TR25-12		B6	*K. lateritia* var. *lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	8.14	Qubit	0.71	2
TR25-13		B7	*K. lateritia* var. *lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	11	Qubit	1.04	2
TR25-05		B8	*K. nyikae* subsp. *nyikae*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	6.52	Qubit	0.83	2
GE03-13		C1	*K. nyikae* subsp. *auriculata*	Degraded	EB (E.Z.N.A. mini-plant kit)	94	7.5	Qubit	0.65	3
TR13-06		C2	*K. blossfeldiana*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	13.7	Qubit	0.84	3
TR14-08		C3	*K. paniculata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	15.7	Qubit	1.33	3

TR21-09		C4	*K. daigremontiana*	Degraded	EB (E.Z.N.A. mini-plant kit)	31	19.1	Qubit	2.04	3
TR23-12		C5	*K. pinnata*	Degraded	EB (E.Z.N.A. mini-plant kit)	46	13.1	Qubit	0.93	3
TR25-03		C6	*K. nyikae* subsp. *auriculata* (isotype)	Degraded	EB (E.Z.N.A. mini-plant kit)	48	14.9	Qubit	0.6	3
TR25-10		C7	*K. lateritia* var. *prostrata*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	13.6	Qubit	0.81	3
TRF-04		C8	*K. brachyloba*	Degraded	EB (E.Z.N.A. mini-plant kit)	124	5.01	Qubit	0.45	3
TRF-08		C9	*K. integrifolia*	Degraded	EB (E.Z.N.A. mini-plant kit)	124	5.44	Qubit	0.59	3
TRF-16		C10	*K. thyrsiflora*	Degraded	EB (E.Z.N.A. mini-plant kit)	79	8.23	Qubit	0.69	3
GE03-14		D1	*K. laterita* var. *pseudolateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	94	13.1	Qubit	0.83	4
TR16-13		D2	*K. welwitschii*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	24.1	Qubit	0.47	4
TR20-01		D3	*K. luciae*	Degraded	EB (E.Z.N.A. mini-plant kit)	31	24.4	Qubit	0.93	4
TR20-03		D4	*K. neglacta*	Degraded	EB (E.Z.N.A. mini-plant kit)	31	31.5	Qubit	1.51	4
TR23-08		D5	*K. usambarensis*	Degraded	EB (E.Z.N.A. mini-plant kit)	46	21.3	Qubit	0.96	4
TR23-11		D6	*K. peteri*	Degraded	EB (E.Z.N.A. mini-plant kit)	46	29.5	Qubit	1.01	4
TR25-01		D7	*K. nyikae* subsp. *auriculata*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	17.1	Qubit	0.8	4
TR25-08		D8	*K. laterita* var. *pseudolateritia* (isotype)	Degraded	EB (E.Z.N.A. mini-plant kit)	48	16.2	Qubit	0.71	4
TR09-11		D9	*K. crundallii*	Degraded	EB (E.Z.N.A. mini-plant kit)	36	30	Qubit	0.61	4
TRF-12		D10	*K. longiflora*	Degraded	EB (E.Z.N.A. mini-plant kit)	81	15.9	Qubit	1.12	4
GE0		E1	*K. aubrevillei*	Degr	EB (E.Z.N.A.	44	27.4	Qubit	0.92	5

3-19				aded	mini-plant kit)					
TR14-09		E2	*K. quartiniana*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	35.6	Qubit	0.76	5
TR18-10		E3	*K. deficiens*	Degraded	EB (E.Z.N.A. mini-plant kit)	76	36.3	Qubit	0.96	5
TR21-07		E4	*K. petitiana*	Degraded	EB (E.Z.N.A. mini-plant kit)	39	38.1	Qubit	1.06	5
TR22-05		E5	*K. prolifera*	Degraded	EB (E.Z.N.A. mini-plant kit)	39	27.1	Qubit	1.32	5
TR23-06		E6	*K. boranae*	Degraded	EB (E.Z.N.A. mini-plant kit)	43	28.1	Qubit	0.82	5
TR23-10		E7	*K. germanae*	Degraded	EB (E.Z.N.A. mini-plant kit)	46	14.2	Qubit	0.66	5
TR09-08		E8	*K. latisepala*	Degraded	EB (E.Z.N.A. mini-plant kit)	36	38.9	Qubit	1.04	5
TRF-06		E9	*K. elizae*	Degraded	EB (E.Z.N.A. mini-plant kit)	81	26.6	Qubit	1.6	5
TRF-13		E10	*K. stenosiphon*	Degraded	EB (E.Z.N.A. mini-plant kit)	81	22.4	Qubit	0.8	5
TR10-08		F1	*K. lateritia* cf. *prostrata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	10.3	Qubit	0.95	6
TR10-11		F2	*K. lateritia* cf. *lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	19.8	Qubit	1.04	6
TR12-07		F3	*K. lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	24.6	Qubit	1.33	6
TR14-03		F4	*K. hametiorum*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	22.7	Qubit	1.14	6
TR15-01		F5	*K. lineariflora*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	23.1	Qubit	1.3	6
TR16-04		F6	*K. delagoensis*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	14.7	Qubit	1.31	6
TR16-11		F7	*K. yemensis*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	17.2	Qubit	0.99	6
TR17-05		F9	*K. sp*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	30.3	Qubit	1.32	6

TR23-05		F10	*K. bipartita*	Degraded	EB (E.Z.N.A. mini-plant kit)	43	31.6	Qubit	0.63	6
TR09-07		F11	*K. sexangularis*	Degraded	EB (E.Z.N.A. mini-plant kit)	36	27.9	Qubit	0.88	6
TR10-06		G1	*K. lanceolata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	37.4	Qubit	1.71	7
TR12-01		G2	*K. crenata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	32.6	Qubit	1.82	7
TR12-02		G3	*K. nyikae* subsp. *nyikae*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33	Qubit	1.96	7
TR12-08		G4	*K. lateritia* cf. *lateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	30.5	Qubit	1.61	7
TR12-09		G5	*K. lateritia* var. *pseudolateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	37.9	Qubit	1.78	7
TR12-10		G6	*K. lateritia* cf. *prostrata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	27.1	Qubit	1.8	7
TR17-02		G7	*K. sp*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	23.6	Qubit	1.83	7
TR17-03		G8	*K. sp*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	32.8	Qubit	1.93	7
TR17-06		G9	*K. sp*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33.8	Qubit	1.97	7
TR17-07		G10	*K. sp*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	33.2	Qubit	1.94	7
TR17-11		G11	*K. lateritia* var. *pseudolateritia*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	26.5	Qubit	1.93	7
TR17-12		G12	*K. lateritia* var. *prostrata*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	25.6	Qubit	1.72	7
GE03-25		H1	*K. ballyi*	Degraded	EB (E.Z.N.A. mini-plant kit)	36	47.2	Qubit	1.79	8
TR10-02		H2	*K. citrina*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	44.4	Qubit	1.71	8
TR10-04		H3	*K. obtusa*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	39.2	Qubit	1.54	8
TR08		H4	*K. sp.*	Degr	EB (E.Z.N.A.	51	37.9	Qubit	1.64	8

-10				aded	mini-plant kit)						
TR12-11		H5	*Cotyledon barbeyi*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	38.9	Qubit	1.87	8	
TR17-10		H6	*K. lateritia* var. *lateritia /aubrevillei*	Degraded	EB (E.Z.N.A. mini-plant kit)	41	42.4	Qubit	2.1	8	
TR27-01		H7	*K. marmorata*	Degraded	EB (E.Z.N.A. mini-plant kit)	48	44.4	Qubit	1.86	8	
TR08-02		H8	*K. glaucescens*	Degraded	EB (E.Z.N.A. mini-plant kit)	51	54	Qubit	1.87	8	
TR08-04		H9	*K. densiflora* var. *densiflora*	Degraded	EB (E.Z.N.A. mini-plant kit)	51	48.1	Qubit	2.22	8	
TR08-05		H10	*K. laciniata*	Degraded	EB (E.Z.N.A. mini-plant kit)	51	37.7	Qubit	1.94	8	
TR08-09		H11	*K. mitejea*	Degraded	EB (E.Z.N.A. mini-plant kit)	51	39.8	Qubit	2.13	8	
TR08-11		H12	*K. prittwitzii*	Degraded	EB (E.Z.N.A. mini-plant kit)	51	42.8	Qubit	2.01	8	

AND/ OR

Library Information

Sample ID	Tube Label	Well Position (plates only)	Organism	Platform (Illumina, Torrent)	Style (Truseq, Nextera)	Index Config (dual, single)	Index 1 Sequence (i7 or Torrent)	Index 2 Sequence (i5)	Volume* (µL)	Conc. (ng/µL)	Quant method (Qubit, etc)	Group ID

Arbor Biosciences myReads® Project Sample Submission – DNA

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INCLUDE a signed and dated print copy of this form with your shipment (scan sheet to ~70% for printing)
NEVER ship irreplaceable materials

v180820

SAMPLE INFORMATION

CLIENT NAME	Tor K. R. Johansen
CLIENT INSTITUTION	NHM, University of Oslo
NUMBER OF SAMPLES	88
QUOTE NUMBER	
myReads PROJECT ID	GT_NHM_31
FORM FILL DATE	5/13/2020

NOTES

Group 5+6 should be divided into two new groups based on your expertise. All groups can be changed/adjusted if required for better sequencing results.

gDNA Information

Sample ID	Tube Label	Well Position (plate only)	Organism	State (fresh, degraded)	Medium (DESS, TE, EtOH, Blood)	Volume^ (µL)	Concentr. (ng/µL)	Quant method (Qubit, etc)	UV 260:280 ratio	Group ID
GED3-16		A1	*K. nylkire subsp. nylkire*	Degraded	EB (E.Z.N.A. miniprep kit)	94	1.61	Qubit	0.76	1
TR23-01		A2	*K. sp. A (FTEA)*	Degraded	EB (E.Z.N.A. miniprep kit)	100	2.12	Qubit	0.91	1
TR23-09		A3	*K. hemilis*	Degraded	EB (E.Z.N.A. miniprep kit)	46	4.26	Qubit	0.78	1
TR26-02		A4	*K. nylkire subsp. barbicharla*	Degraded	EB (E.Z.N.A. miniprep kit)	48	4.6	Qubit	0.76	1
TRF-11		A5	*K. tebricache*	Degraded	EB (E.Z.N.A. miniprep kit)	48	3.14	Qubit	0.46	1
TR26-06		A6	*K. nylkire subsp. nylkire (isotype)*	Degraded	EB (E.Z.N.A. miniprep kit)	48	2.3	Qubit	0.44	1
TR26-07		A7	*K. tebentite var. prostrata*	Degraded	EB (E.Z.N.A. miniprep kit)	48	2.3	Qubit	0.69	1
TR26-09		A8	*K. tebentite var. prostrata (isotype)*	Degraded	EB (E.Z.N.A. miniprep kit)	98	2.86	Qubit	0.69	1
TR18-12		B1	*K. antcom*	Degraded	EB (E.Z.N.A. miniprep kit)	41	9.62	Qubit	0.88	2
TR22-09		B2	*K. cam pannulata*	Degraded	EB (E.Z.N.A. miniprep kit)	38	13.6	Qubit	1.38	2
TR23-02		B3	*K. sp.5 (FTEA)*	Degraded	EB (E.Z.N.A. miniprep kit)	43	11.4	Qubit	0.44	2
TR26-04		B4	*K. nylkire subsp. nylkire*	Degraded	EB (E.Z.N.A. miniprep kit)	48	7.32	Qubit	0.61	2
TR26-11		B5	*K. tebentite var. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	48	7.35	Qubit	0.69	2
TR26-12		B6	*K. tebentite var. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	48	8.14	Qubit	0.71	2
TR26-13		B7	*K. tebentite var. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	48	11	Qubit	1.04	2
TR26-05		B8	*K. nylkire subsp. nylkire*	Degraded	EB (E.Z.N.A. miniprep kit)	48	6.62	Qubit	0.83	2
GED3-13		C1	*K. nylkire subsp. barbicharla*	Degraded	EB (E.Z.N.A. miniprep kit)	94	7.6	Qubit	0.66	3
TR13-06		C2	*K. blossfeldiana*	Degraded	EB (E.Z.N.A. miniprep kit)	41	13.7	Qubit	0.84	3
TR14-08		C3	*K. pinnulata*	Degraded	EB (E.Z.N.A. miniprep kit)	41	16.7	Qubit	1.33	3
TR21-09		C4	*K. delpinoi subsp.*	Degraded	EB (E.Z.N.A. miniprep kit)	31	19.1	Qubit	2.04	3
TR23-12		C5	*K. gloneae*	Degraded	EB (E.Z.N.A. miniprep kit)	46	13.1	Qubit	0.93	3
TR26-03		C6	*K. nylkire subsp. barbicharla (isotype)*	Degraded	EB (E.Z.N.A. miniprep kit)	48	14.9	Qubit	0.6	3
TR26-10		C7	*K. tebentite var. prostrata*	Degraded	EB (E.Z.N.A. miniprep kit)	48	13.6	Qubit	0.81	3
TRF-04		C8	*K. brachyboia*	Degraded	EB (E.Z.N.A. miniprep kit)	124	5.01	Qubit	0.46	3
TRF-08		C9	*K. integrifolia*	Degraded	EB (E.Z.N.A. miniprep kit)	124	5.44	Qubit	0.59	3
TRF-16		C10	*K. thyrsiflora*	Degraded	EB (E.Z.N.A. miniprep kit)	79	8.23	Qubit	0.69	3
GED3-14		D1	*K. tebentite var. pseudotebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	94	13.1	Qubit	0.83	4
TR16-13		D2	*K. velutibohii*	Degraded	EB (E.Z.N.A. miniprep kit)	41	24.1	Qubit	0.47	4
TR20-01		D3	*K. laciniata*	Degraded	EB (E.Z.N.A. miniprep kit)	31	24.4	Qubit	0.93	4
TR20-03		D4	*K. neglecta*	Degraded	EB (E.Z.N.A. miniprep kit)	31	31.6	Qubit	1.51	4
TR23-08		D5	*K. wilmsii brevis*	Degraded	EB (E.Z.N.A. miniprep kit)	46	21.3	Qubit	0.96	4
TR23-11		D6	*K. petri*	Degraded	EB (E.Z.N.A. miniprep kit)	46	29.6	Qubit	1.01	4
TR26-01		D7	*K. nylkire subsp. barbicharla*	Degraded	EB (E.Z.N.A. miniprep kit)	48	17.1	Qubit	0.8	4
TR26-08		D8	*K. tebentite var. pseudotebentite (isotype)*	Degraded	EB (E.Z.N.A. miniprep kit)	48	16.2	Qubit	0.71	4
TR09-11		D9	*K. cremoidii*	Degraded	EB (E.Z.N.A. miniprep kit)	36	30	Qubit	0.61	4
TRF-12		D10	*K. longiflora*	Degraded	EB (E.Z.N.A. miniprep kit)	81	15.9	Qubit	1.12	4
GED3-19		E1	*K. uschewiiol*	Degraded	EB (E.Z.N.A. miniprep kit)	44	27.4	Qubit	0.92	5
TR14-09		E2	*K. gerethiana*	Degraded	EB (E.Z.N.A. miniprep kit)	41	35.6	Qubit	0.76	5
TR18-10		E3	*K. delticola s*	Degraded	EB (E.Z.N.A. miniprep kit)	16	36.3	Qubit	0.96	5
TR21-07		E4	*K. pellitera*	Degraded	EB (E.Z.N.A. miniprep kit)	39	38.1	Qubit	1.06	5
TR22-05		E5	*K. prolifera*	Degraded	EB (E.Z.N.A. miniprep kit)	39	27.1	Qubit	1.32	5
TR23-06		E6	*K. boiviana*	Degraded	EB (E.Z.N.A. miniprep kit)	43	28.1	Qubit	0.82	5
TR23-10		E7	*K. gerrardiana*	Degraded	EB (E.Z.N.A. miniprep kit)	46	14.2	Qubit	0.66	5
TR09-08		E8	*K. tetrapeta*	Degraded	EB (E.Z.N.A. miniprep kit)	36	38.9	Qubit	1.04	5
TRF-06		E9	*K. wilcoxii*	Degraded	EB (E.Z.N.A. miniprep kit)	81	26.6	Qubit	1.6	5
TRF-13		E10	*K. stenophylion*	Degraded	EB (E.Z.N.A. miniprep kit)	81	22.4	Qubit	0.8	5
TR10-08		F1	*K. tebentite cf. prostrata*	Degraded	EB (E.Z.N.A. miniprep kit)	41	10.3	Qubit	0.95	6
TR10-11		F2	*K. tebentite cf. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	41	19.8	Qubit	1.04	6
TR12-07		F3	*K. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	41	24.6	Qubit	1.33	6
TR14-03		F4	*K. hemitoreum*	Degraded	EB (E.Z.N.A. miniprep kit)	41	22.7	Qubit	1.14	6
TR15-01		F5	*K. limnitidis*	Degraded	EB (E.Z.N.A. miniprep kit)	41	23.1	Qubit	1.3	6
TR16-04		F6	*K. delingoensis*	Degraded	EB (E.Z.N.A. miniprep kit)	41	14.7	Qubit	1.31	6
TR16-11		F7	*K. yemensis*	Degraded	EB (E.Z.N.A. miniprep kit)	41	17.2	Qubit	0.99	6
TR17-05		F9	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	41	30.3	Qubit	1.32	6
TR23-05		F10	*K. bijarita*	Degraded	EB (E.Z.N.A. miniprep kit)	43	31.6	Qubit	0.69	6
TR09-07		F11	*K. sempervivens*	Degraded	EB (E.Z.N.A. miniprep kit)	36	27.9	Qubit	0.88	6
TR10-06		G1	*K. lanceolata*	Degraded	EB (E.Z.N.A. miniprep kit)	41	37.4	Qubit	1.71	7
TR12-01		G2	*K. orientalis*	Degraded	EB (E.Z.N.A. miniprep kit)	41	32.6	Qubit	1.82	7
TR12-02		G3	*K. nylkire subsp.nylkire*	Degraded	EB (E.Z.N.A. miniprep kit)	41	33	Qubit	1.96	7
TR12-08		G4	*K. tebentite cf. tebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	41	30.5	Qubit	1.61	7
TR12-09		G5	*K. tebentite var. pseudotebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	41	37.9	Qubit	1.78	7
TR12-10		G6	*K. tebentite cf. prostrata*	Degraded	EB (E.Z.N.A. miniprep kit)	41	27.1	Qubit	1.8	7
TR17-02		G7	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	41	23.6	Qubit	1.83	7
TR17-03		G8	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	41	32.8	Qubit	1.93	7
TR17-06		G9	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	41	33.8	Qubit	1.97	7
TR17-07		G10	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	41	33.2	Qubit	1.94	7
TR17-11		G11	*K. tebentite var. pseudotebentite*	Degraded	EB (E.Z.N.A. miniprep kit)	41	26.5	Qubit	1.93	7
TR17-12		G12	*K. tebentite var. prostrata*	Degraded	EB (E.Z.N.A. miniprep kit)	41	26.6	Qubit	1.72	7
GED3-20		H1	*K. bellyi*	Degraded	EB (E.Z.N.A. miniprep kit)	36	47.2	Qubit	1.79	8
TR10-02		H2	*K. citrina*	Degraded	EB (E.Z.N.A. miniprep kit)	41	44.4	Qubit	1.71	8
TR10-04		H3	*K. obrisa*	Degraded	EB (E.Z.N.A. miniprep kit)	41	39.2	Qubit	1.54	8
TR08-10		H4	*K. sp.*	Degraded	EB (E.Z.N.A. miniprep kit)	51	37.9	Qubit	1.64	8
TR12-11		H5	*Cotyledon barbeyi*	Degraded	EB (E.Z.N.A. miniprep kit)	41	38.9	Qubit	1.87	8
TR17-10		H6	*K. tebentite var. tebentite Arabuko*	Degraded	EB (E.Z.N.A. miniprep kit)	41	42.4	Qubit	2.1	8
TR27-01		H7	*K. nyemsonii*	Degraded	EB (E.Z.N.A. miniprep kit)	48	44.4	Qubit	1.86	8
TR08-02		H8	*K. glaucescens*	Degraded	EB (E.Z.N.A. miniprep kit)	51	54	Qubit	1.87	8
TR08-04		H9	*K. olenshonii var. olenshonii*	Degraded	EB (E.Z.N.A. miniprep kit)	51	48.1	Qubit	2.22	8
TR09-06		H10	*K. teclensis*	Degraded	EB (E.Z.N.A. miniprep kit)	51	37.7	Qubit	1.94	8
TR09-09		H11	*K. millepes*	Degraded	EB (E.Z.N.A. miniprep kit)	51	39.8	Qubit	2.13	8
TR09-11		H12	*K. gilfillanii*	Degraded	EB (E.Z.N.A. miniprep kit)	51	42.8	Qubit	2.01	8

ANDOR

Library Information

Sample ID	Tube Label	Well Position (plate only)	Organism	Platform (Illumina, Torrent)	Style (Truseq, Nextera)	Index Config (dual, single)	Index 1 Sequence (for Torrent)	Index 2 Sequence (i5)	Volume^ (µL)	Conc. (ng/µL)	Quant method (Kapa, etc)	Group ID

Appendix 9: Molecular Work Samples and Primers

ARBOR BIOSCIENCES - myReads Project TL02- Demultiplexing stats - 2jk

Sample ID	i7 Index	i5 Index	Seqrun ID	PF Reads	% of >= Q30 Bases (PF)
GE03-15	ATTACTCG	AGCCATGC	7011-JK-1_001	4,306,769	75.66
TR23-01	TCCGGAGA	GTACGCAA	7011-JK-1_002	1,157,491	66.63
TR23-09	CGCTCATT	AGTACAAG	7011-JK-1_003	1,569,059	82.85
TR25-02	GAGATTCC	ACATTGGC	7011-JK-1_004	3,436,904	86.1
TRF-11	ATTCAGAA	ATTGAGGA	7011-JK-1_005	3,514,456	86.97
TR25-06	GAATTCGT	GTCGTAGA	7011-JK-1_006	5,310,128	85.99
TR25-07	CTGAAGCT	AGAGTCAA	7011-JK-1_007	7,753,373	87.57
TR25-09	TAATGCGC	CCGACAAC	7011-JK-1_008	18,463,114	91.99
TR15-12	ATGCCTAA	AGATCGCA	7011-JK-1_009	4,067,557	85.37
TR22-09	GAATCTGA	AAGAGATC	7011-JK-1_010	8,760,853	89.64
TR23-02	AACGTGAT	CAACCACA	7011-JK-1_011	202,354	86.86
TR25-04	CACTTCGA	TGGAACAA	7011-JK-1_012	5,954,839	88.52
TR25-11	GCCAAGAC	CCTCTATC	7011-JK-1_013	567,698	73.59
TR25-12	GACTAGTA	ACAGATTC	7011-JK-1_014	13,041,633	90.5
TR25-13	ATTGGCTC	CCAGTTCA	7011-JK-1_015	4,743,744	90.31
TR25-05	GATGAATC	TGGCTTCA	7011-JK-1_016	4,744,482	85.4
GE03-13	CGAACTTA	AACAACCA	7011-JK-1_017	9,400,126	88.14
TR13-06	GATAGACA	AATCCGTC	7011-JK-1_018	5,098,798	86.27
TR14-08	AAGGACAC	CAAGGAGC	7011-JK-1_019	22,991,318	90.47
TR21-09	GACAGTGC	TTCACGCA	7011-JK-1_020	12,497,522	89.96
TR23-12	ATCATTCC	CACCTTAC	7011-JK-1_021	3,306,085	84.77
TR25-03	GCCACATA	AAGACGGA	7011-JK-1_022	2,788,238	86.87
TR25-10	ACCACTGT	ACACAGAA	7011-JK-1_023	1,849,216	76.51
TRF-04	CTGGCATA	GAACAGGC	7011-JK-1_024	4,485,519	87.57
TRF-08	ACCTCCAA	AACCGAGA	7011-JK-1_025	630,804	85.26
TRF-16	GCGAGTAA	ACAAGCTA	7011-JK-1_026	2,869,127	86.43
GE03-14	CCGTGAGA	AATGAGCG	7011-JK-1_027	8,354,053	86.35
TR16-13	GTGTTCTA	GGAATCTC	7011-JK-1_028	316,049	82.56
TR20-01	CAATGGAA	TTCTGAAT	7011-JK-1_029	10,437,065	89.35
TR20-03	AGCACCTC	ACGAATTC	7011-JK-1_030	1,934,149	88.63
TR23-08	CAGCGTTA	AGCTTCAG	7011-JK-1_031	1,573,042	82.1
TR23-11	TAGGATGA	GCGCATTA	7011-JK-1_032	9,791,687	88.73
TR25-01	ACCGATCA	CATAGCCG	7011-JK-1_033	6,380,891	85.8
TR25-08	ACAGCAGA	TTCGCGGA	7011-JK-1_034	8,893,310	86.81
TR09-11	CATACCAA	GCGCGAGA	7011-JK-1_035	9,374,840	89.27
TRF-12	TATCAGCA	CTATCGCT	7011-JK-1_036	2,423,852	87.54
GE03-19	CTCAATGA	ATCACGTT	7011-JK-1_037	2,064,709	83.97
TR14-09	TCCGTCTA	TCGAAGTG	7011-JK-1_038	4,807,973	91.03
TR18-10	AGGCTAAC	GTCTTGGC	7011-JK-1_039	4,192,243	90.19
TR21-07	CCATCCTC	TACTAGTC	7011-JK-1_040	7,700,928	90.69
TR22-05	AGATGTAC	GAGCCAAT	7011-JK-1_041	4,982,502	91
TR23-06	TCTTCACA	GATTCATC	7011-JK-1_042	3,184,892	88.35
TR23-10	CCGAAGTA	TTCCTGCT	7011-JK-1_043	494,439	84.87
TR09-08	CGCATACA	TTCAGCTC	7011-JK-1_044	5,493,468	90.43
TRF-06	AATGTTGC	CGATGTTT	7011-JK-1_045	5,468,380	90.72
TRF-13	TGAAGAGA	GCTAACTC	7011-JK-1_046	3,732,703	90.13
TR10-08	AGGATAGG	TTCCATTG	7011-JK-1_047	4,018,134	90.23
TR10-11	TCAGAGCC	GAGGTGCT	7011-JK-1_048	4,352,724	90.41
TR12-07	CTTCGCCT	TAACGCTG	7011-JK-1_049	4,002,373	90.48
TR14-03	TAAGATTA	TCATCCTA	7011-JK-1_050	11,445,608	91.22
TR15-01	ACGTCCTG	TGACCACT	7011-JK-1_051	3,472,586	90.92
TR16-04	GTCAGTAC	TCTGCTGT	7011-JK-1_052	3,563,906	90.78
TR16-11	GGTGAGTT	TTGGTATG	7011-JK-1_053	6,381,450	90.91
TR17-05	CAGATCTG	GTCGCTAT	7011-JK-1_054	4,478,751	90.56
TR23-05	TACAGGAT	TCGAGCGT	7011-JK-1_055	4,939,408	90.97
TR09-07	GGCTACAG	GACCTGTA	7011-JK-1_056	416,602	61.3

TR10-06	GGTCGTGT	GGCAGATC	7011-JK-1_057	4,364,720	91.08
TR12-01	TAGTGACT	CTATGTTA	7011-JK-1_058	5,858,235	90.13
TR12-02	TAAGCGTT	GTTGACGC	7011-JK-1_059	6,748,444	90.49
TR12-08	TGTTCTCC	ATCTACGA	7011-JK-1_060	5,468,056	89.98
TR12-09	ACTTGATG	CTCGACAG	7011-JK-1_061	5,383,231	90.22
TR12-10	TGTACCTT	GAGGCTGC	7011-JK-1_062	7,360,964	90.87
TR17-02	GATCAGCG	CCTCGTAG	7011-JK-1_063	5,201,556	90.43
TR17-03	TTCGCACC	CATAGGCA	7011-JK-1_064	3,411,638	88.9
TR17-06	GGATTAGG	AGATGAAC	7011-JK-1_065	4,331,165	90.43
TR17-07	TGGCTCAG	CCGAGTAT	7011-JK-1_066	3,454,307	90.32
TR17-11	GCATGGCT	AATATTGA	7011-JK-1_067	4,084,562	90.53
TR17-12	TTGCGTAC	GTATACCG	7011-JK-1_068	4,332,901	90.26
GE03-25	CTTGTACT	GATCCAAC	7011-JK-1_069	4,786,713	89.74
TR10-02	GCCAATGT	AGATACGC	7011-JK-1_070	4,468,779	89.73
TR10-04	TCCTCAAT	GGTATCTT	7011-JK-1_071	4,954,448	89.93
TR08-10	TCTACGAC	CCTCTGGC	7011-JK-1_072	4,490,945	90.34
TR12-11	TTGACTCT	CCATTGTG	7011-JK-1_073	4,746,170	90.56
TR17-10	GTTGTCGG	CAAGGTAG	7011-JK-1_074	4,439,816	89.79
TR27-01	TGATACGT	AAGTGCTA	7011-JK-1_075	5,284,688	90.04
TR08-02	TGACAGAC	GCCGAACG	7011-JK-1_076	3,834,172	89.77
TR08-04	GACCTTAG	TGTCCACG	7011-JK-1_077	4,037,039	90.37
TR08-05	GTGTGTCG	GACACACT	7011-JK-1_078	3,471,605	89.66
TR08-09	TGCGATCT	AATATGCT	7011-JK-1_079	3,489,612	90.09
TR08-11	GATCTCTT	TTCTCATA	7011-JK-1_080	4,450,219	90.3

Appendix 10: Protocols Used in Molecular Work

DNA EXTRACTION PROTOCOL WITH E.Z.N.A. SP PLANT MINI KIT			
Aim	Extract DNA from (dried) plant material		
Date	08.12.14 – last update 03.10.19	Performed by:	Lisbeth

Remarks:

- All centrifugation steps are carried out at room temperature (15–25°C) in a Microcentrifuge.
- According to the manual the starting amount for dry tissue samples is 10-30 mg. In practice a piece of leaf of about 0,25 cm^2 works well. Don't exceed ~1 cm^2 as it will reduce yield and purity.

Before starting:

- Buffer SP3 and Buffer SPW Wash are supplied as concentrates. Before using for the first time, add the appropriate amount of ethanol (96–100%) as indicated on page 6 in the handbook.

Before starting the day:

- Buffer SP1 and SP3 may form precipitates upon storage. If necessary, warm them to redissolve. Do not heat SP3 to more than 37 °C if ethanol has been added.
- Preheat an incubator or heating block to 65°C.
- Heat elutionbuffer to 65°C.
- Get ice.
- Label tubes. 1 x 1,5 ml Eppendorf tubes
  1 x Homogenizer columns and collection tubes
  1 x HiBind columns and collection tubes
  1 x collection tubes
  1 or 2 x safe lock 1,5 ml Eppendorf tubes for elutes

Protocol:

1. Add the dried sample to a 2 ml tube containing 2 tungsten-carbide beads. Sterilize the tweezers.

2. Place the tubes into the TissueLyser Adapter Set 2 x 24, and fix into the clamps of the TissueLyser. Immediately grind the samples for about 1 min at (max) 25 Hz depending on the sample type.

3. Repeat step 2, reversing the position of the adaptors. If the samples are not crushed repeat step 2 and 3 until it's a crushed to a fine power.

4. Cover the tube lid with a kimtech-wipe when you open it to avoid dust flying all over. Only open one at the time.

5. Add 600 µL SP1 Buffer and 5 µL RNase A. Vortex at maximum speed to mix thoroughly. Do not mix SP1 Buffer and RNase A before use.

   Note: Ensure that all the samples are completely suspended and that there are no clumps in the solution. Clumps will result in low yields.

6. Incubate at 65°C for 10 minutes to 1 hour. Mix samples frequently during incubation by inverting the tube.

7. Add 210 µL SP2 Buffer. Vortex to mix thoroughly.

8. Let sit on ice for 5 minutes.

9. Centrifuge at maximum speed (≥10,000 x *g*) for 10 minutes.

10. Insert a Homogenizer Column into a 2 mL Collection Tube.

11. Carefully transfer the supernatant (**up to 650 µl**) to the Homogenizer Column. Do not disturb or transfer any of the insoluble pellet.
12. Immediately centrifuge at maximum speed for 2 minutes.
    Note: Longer centrifugation does not improve yield. The Homogenizer Column will remove most remaining precipitates and cell debris, but a small amount may pass through and form a pellet in the collection tube. Be careful not to disturb this pellet in Step 13.

13. Transfer cleared lysate to a 1.5 mL microcentrifuge tube (**550 µl**). Do not disturb or transfer any of the insoluble pellet. Measure the volume of the lysate.

14. Add 1.5 volumes SP3 Buffer (**825 µl**). Vortex immediately to obtain a homogenous mixture.
    A precipitate may form at this point; it will not interfere with DNA isolation.

    Note: SP3 Buffer must be diluted with ethanol before use.

15. Insert a HiBind DNA Mini Column into a 2 mL Collection Tube.

16. Transfer 650 µL sample to the HiBind® DNA Mini Column.
17. Centrifuge at maximum speed for 1 minute.
18. Discard filtrate and reuse the collection tube.
19. Repeat Steps 16-18 until all of the sample has been transferred to the column.
20. Transfer the HiBind® DNA Mini Column to a new 2 mL Collection Tube.
21. Add 650 µL SPW Wash Buffer. Flip the columns up-side-down.

    Note: SPW Wash Buffer must be diluted with ethanol before use.

22. Centrifuge at maximum speed for 1 minute.

23. Discard filtrate and reuse the collection tube.
24. Repeat Steps 21-23 for a second SPW Wash Buffer wash step.

25. Centrifuge the empty HiBind DNA Mini Column at maximum speed for 2 minutes to dry he column.

    Note: This step is critical for removal of trace ethanol that may interfere with downstream applications.
    Transfer the HiBind DNA Mini Column into a clean 1.5 mL microcentrifuge tube.

26. Add 50-100 µL Elution Buffer heated to 65°C.

27. Let sit at room temperature for 3-5 minutes.

    Note: Elution at 65 °C may increase yield.

28. Centrifuge at maximum speed for 1 minute.

29. Repeat Steps 27-29 for a second elution step.

30. Store eluted DNA at -20°C for long term storage and at 4 °C for short.

RUNNING AN ELECTROPHORESIS GEL

Always use gloves in the gel electrophoresis room!
Always remove gloves before leaving the room!

Buffers:

The default buffer is 1X TAE. ALWAYS make new 1X TAE-buffer after emptying one of the reagent bottles on the shelf. To make new add 100 ml of 10X TAE and 900 ml of dH_2O into a one liter reagent bottle, then mix by turning it upside down 3 times.

If the buffer in the electrophoresis chamber is old (2-3 weeks or 5-10 runs) empty it in the bottle in the sink. Refill the electrophoresis chamber with 1X TAE from the reagent bottles. Add a new piece of tape on the lid and write down the date. If you use another buffer (i.e. 0.5 TAE or TBE) mark it clearly on the tape. To keep track, remember to add a mark on the tape after each gel electrophoresis run.

Gels:

Small electrophoresis chamber: 50 ml gel and 2 µl GelRed.
Max 28 wells (2*14)

Medium electrophoresis chamber: 65 ml gel and 3 µl GelRed.
Max 60 wells (2*30)

Large electrophoresis chamber: 160 ml gel and 6 µl GelRed.
Max 200 wells (4*50)

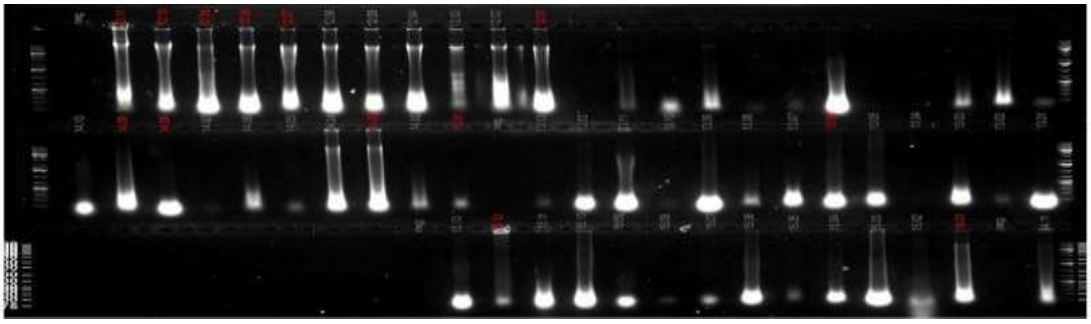
You can store agarose in your own reagent bottle in the heating cabinet (58-60°C). Make agarose using the SeaKem LE agarose (i.e: to make 200 ml of 1% agarose you need 2 grams of SeaKem LE agarose powder and 200 ml of 1X TAE-buffer). Heat in the microwave without the lid tightened until the liquid is clear.

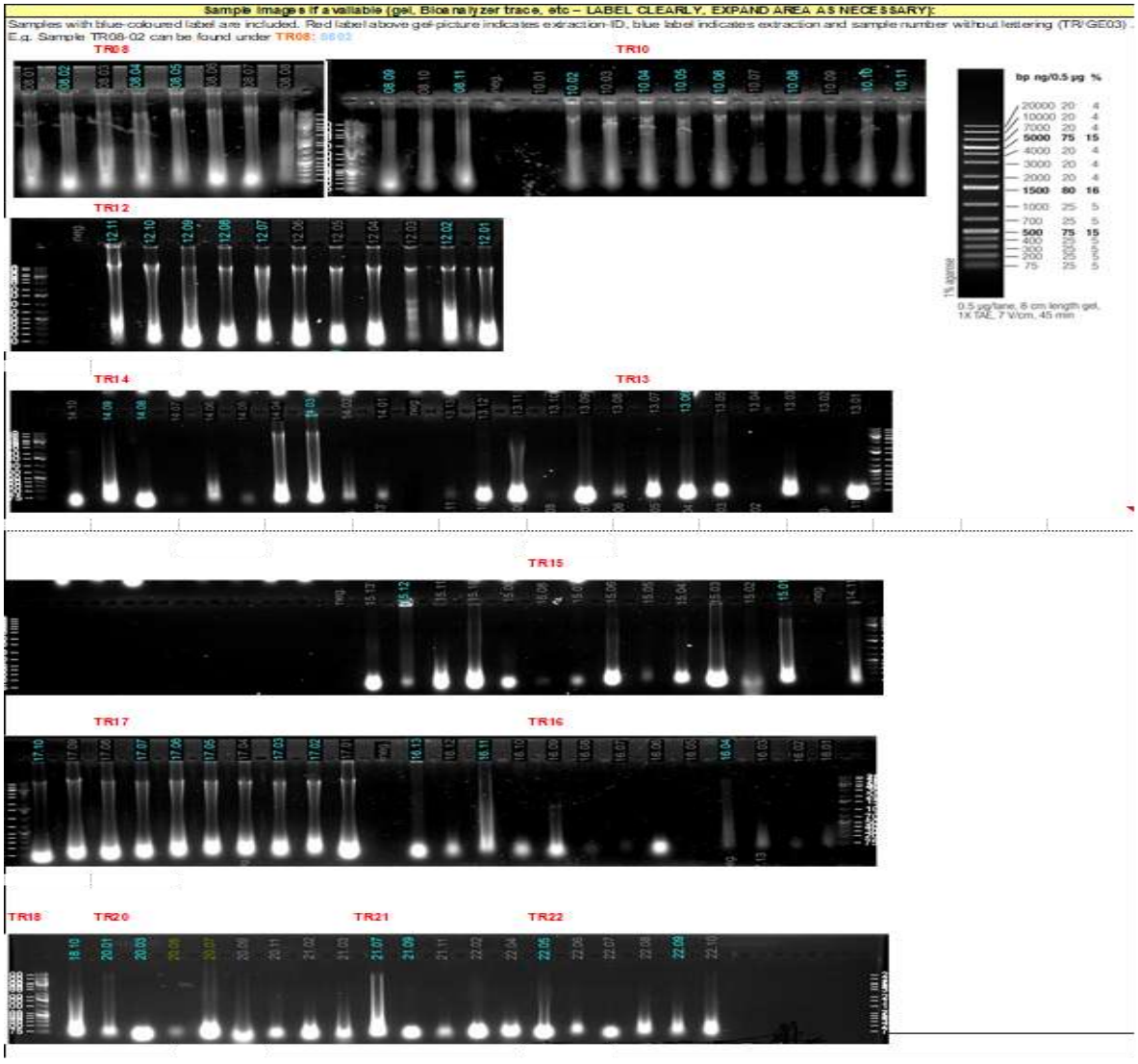
DO NOT pour boiling agarose in to the gel casting trays, they will warp. Wait until the agarose has cooled down to approximately 60°C, or you can hold the bottle without feeling too much pain.

After running the gel and checking it in the BioRad XR+ camera system, throw it in yellow plastic bin ("riskavfall") next to the computer table. When the bin is full tell the lab technicians.

After casting a gel, wash the Erlenmeyer flasks thoroughly using plenty of hot water and a brush. Double check that the flask is clean and there are no gel-remains in the bottle.

Appendix 11: Electrophoresis Gel Micrographs





Appendix 12: Photographs Taken During Field, Herbarium and Laboratory Studies.

Plate 11.4. Photographs Taken During Field and Herbarium Studies in Kenya. A, B**, C, F, G, H, I and J. Field Studies and Molecular studies in Norway. Photos Taken by G.V. Evusa**

Appendix 13: Approval From SGS

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kubps@yahoo.com
dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Internal Memo

FROM: Dean, Graduate School

DATE: 7th July, 2021

REF: 184/37792/17

TO: Ms. Gertrude V. Evusa
C/o Department of Plant Sciences
KENYATTA UNIVERSITY

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that the Graduate School Board at its meeting 25th June, 2021 approved your Ph.D. Research Proposal entitled **"Phylogeny, Taxonomy and Conservation of Kalanchoe (Crassulaceae) in Kenya".**

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed supervision Tracking and Progress Report Forms. The Forms are available at the University's Website under Graduate School webpage downloads.

By copy of this letter, the Registrar (Academic) is hereby requested to grant you substantive registration for your Ph.D. studies.

Thank you.

REUBEN MURIUKI
FOR: DEAN, GRADUATE SCHOOL

c.c. Chairman, Department of Plant Sciences
Registrar (Academic) Att: Mr. Richard Chweya

Supervisors:

1. Dr. Emily Wabuyele
C/o Department of Plant Sciences
KENYATTA UNIVERSITY

2. Dr. Olwen M. Grace
Royal Botanical Gardens,Kew, United Kingdom
C/o Department of Plant Sciences
KENYATTA UNIVERSITY

3. Dr. Grace Gatheri
C/o Department of Plant Sciences
KENYATTA UNIVERSITY

4. Dr. Charlotte Bjora
Natural History Museum, University of Oslo
C/o Department of Plant Sciences
KENYATTA UNIVERSITY

Appendix 14: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 937969

Date of Issue: 21/August/2019

RESEARCH LICENSE

This is to Certify that Ms.. GERTRUDE EVUSA of Kenyatta University, has been licensed to conduct research in Baringo, Bomet, Bungoma, Busia, Garissa, Kajiado, Kakamega, Kericho, Kilifi, Kisii, Kisumu, Kitui, Kwale, Laikipia, Machakos, Makueni, Mombasa, Nairobi, Nakuru, Nandi, Narok, Siaya, Taita-Taveta, Transnzoia, Uasin-Gishu, Vihiga, Westpokot on the topic: PHYLOGENY, TAXONOMY, ETHNOBOTANY AND CONSERVATION OF KALANCHOE (CRASSULACEAE) IN EAST AFRICA for the period ending : 21/August/2020.

License No: NACOSTI/P/19/330

937969

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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Appendix 15: Publications

1. Evusa, G. V., Gatheri, G., Robinson, T. K., Bjorå, C. S., Pearce, T., Grace, O. M., & Wabuyele, E. (2025). *Ethnobotany of the succulent plant genus Kalanchoe (Crassulaceae) in Kenya, East Africa. Journal of East African Natural History, 114*(3), 10 – 40. https://doi.org/10.2982/028.114.0301

Journal of East African Natural History 114(3): 10–40 (2025)

ETHNOBOTANY OF THE SUCCULENT PLANT GENUS KALANCHOE (CRASSULACEAE) IN KENYA, EAST AFRICA

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ABSTRACT

Succulent plants in the genus *Kalanchoe* hold significant biocultural value, yet inadequate information on their uses and identification constrains their utilization and management. This study set out to document the local names, distribution, and uses of *Kalanchoe* in Kenya, engaging 83 participants (32.5% female and 67.5% male) from nine ethnic groups (Kalenjin, Kamba, Kikuyu, Kisii, Luhya, Luo, Maasai, Mijikenda, and Taita) across six flora regions (K2-K7). Using purposive sampling and semi-structured interviews, the study revealed diverse uses of *Kalanchoe*, including treatment of sprains, swellings, wounds, gastrointestinal problems, as an analgesic, and against microbial infections in humans and poultry, relating to their pharmacological properties. The most utilised species are *K. prittwitzii*, *K. densiflora*, and *K. lateritia*, in that order. Threats such as agricultural encroachment and habitat loss underscore the urgency for in situ, *ex situ*, and agricultural conservation strategies to protect the biocultural heritage associated with *Kalanchoe* in Kenya.

Keywords: biocultural heritage, documentation, conservation, medicine, semi-structured interview, underutilisation

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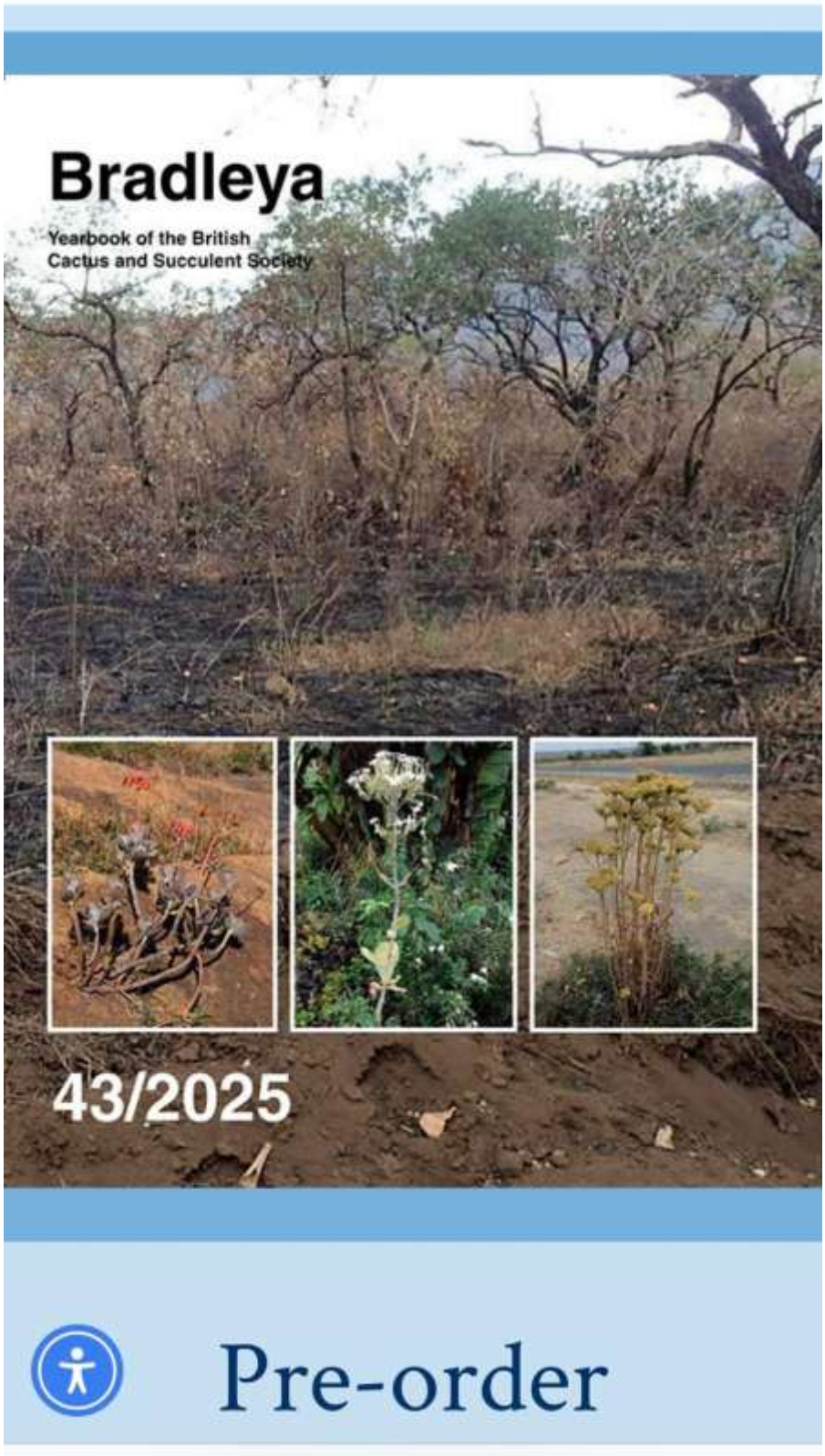
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Current conservation status of the genus *Kalanchoe*

(Crassulaceae) in Kenya, East Africa

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Summary: Kalanchoe is a predominantly leaf succulent plant genus with 174 species whose centres of diversity are in tropical Africa and Madagascar. In Kenya, *Kalanchoe* is represented by 19 species; a few of these (15.8%) have their conservation status categorised as being of Least Concern and need an update, but most (68.4%) have not been assessed at all. The conservation status of *Kalanchoe* indigenous to Kenya was revisited based on field studies and geographical criteria. *Kalanchoe aubrevillei*, *K. boranae* and *K. fadeniorum* were evaluated as Critically Endangered (CR); *K. ballyi*, *K. bipartita, K. citrina, K. glaucescens, K. lateritia, K. marmorata, K. mitejea*, *K. nyikae sensu stricto, K. obtusa* and *K. prittwitzii* were evaluated as Endangered (EN) while *K. crenata*, *K. densiflora*, *K. laciniata* and *K. lanceolata* were evaluated as Vulnerable (VU), all with Area of Occupancy (AOO) of less than 500km^2 following the IUCN (2022) criteria. Additionally, comprehensive evaluation of *K. lateritia* and *K. nyikae sensu stricto* gave an assessment of low AOO. Habitat loss due to degradation and prolonged drought and flooding has reduced the area of occupancy for all the species, possibly

resulting in their reduction in population size and for some, disappearance from their known localities.

Zusammenfassung: *Kalanchoe* ist eine überwiegend blattsukkulente Pflanzengattung mit 174 Arten, deren Diverstitätszentren im tropischen Afrika und auf Madagaskar liegen. In Kenia ist *Kalanchoe* mit 19 Arten vertreten; bei einigen dieser Arten (15,8%) wurde der Erhaltungszustand als wenig besorgniserregend oder als zu aktualisierend eingestuft, die meisten Arten (68,4%) wurden jedoch überhaupt nicht bewertet. Der Erhaltungszustand der in Kenia heimischen *Kalanchoen* wurde auf der Grundlage von Feldstudien und geografischen Kriterien neu bewertet. *Kalanchoe aubrevillei*, *K. boranae* und *K. fadeniorum* wurden als vom Aussterben bedroht (CR) eingestuft; *K. ballyi*, *K. bipartita*, *K. citrina*, *K. glaucescens*, *K. lateritia*, *K. marmorata*, *K. mitejea*, *K. nyikae* sensu stricto, *K. obtusa* und *K. prittwitzii* wurden als stark gefährdet (EN) eingestuft, während *K. crenata*, *K. densiflora*, *K. laciniata* und *K. lanceolata* als gefährdet (VU) eingestuft wurden, alle mit einem effektiv besiedeltem Gebiet (AAO) von weniger als 500km² Größe gemäß den Kriterien der IUCN (2022). Darüber hinaus ergab die umfassende Bewertung von *K. lateritia* und *K. nyikae* sensu stricto niedrige AOO-Werte. Der Lebensraumverlust aufgrund von Lebensraumverschlechterung, anhaltender Trockenheit und Überschwemmungen hat das Verbreitungsgebiet aller Arten reduziert, was möglicherweise zu einer Abnahme der Populations größe und bei einigen Arten zum

Verschwinden an den bekannten Fundorten geführt hat.

Keywords: IUCN, endangered, GeoCAT, habitat loss,