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Population Status, Distribution Patterns and Conservation Needs of Endangered *Croton alienus* Pax in Kenya

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Abstract: Kenya has a very rich plant biodiversity, many which are economically important. However this rich botanical resource continue to decline at an alarming rate as a result of over-exploitation through unsustainable human activities and unpredictable effect of changing climate. Endemic species with restricted geographic ranges and specific habitats are most vulnerable to extinction under the changing environmental and climatical conditions. To aid in their conservation, sound knowledge on their population status, distribution and conservation is urgently needed. The population status, distribution pattern, economic uses and conservation needs of *Croton alienus* Pax 1909, an endemic and endangered plant species in Kenya are reviewed. This was achieved through screening of herbarium specimen at East Africa Herbarium and detailed review of published and un-published research articles. The result indicates, *Croton alienus* has restricted area of occupancy occurring mainly in high altitude region between 1500-1800 m above sea level. Due to its narrow altitude range, *Croton alienus* is restricted to forests in central Kenya (Aberdare forest, Mt Kenya forest), Nairobi region (Karura forest, Ngong forest, Arboretum) and Western Kenya (Kakamega forest). Very low population density of 1 species per hectare in Karura forest suggests urgent conservations needs. Earlier conservations efforts included seed propagation activities to produce seedling, but their sustainability may have been halted by its limited usage. The species is medicinal with antibiotic properties against *Candida albicans* and *Leishmania donovanii* micro-organisms which can be tapped to aid its domestication and conservation. This review highlights need for urgent conservation measures for endemic species with restricted geographic ranges and specific habitat needs like *Croton alienus* in awake of climate change.

Keywords: *Croton alienus*, Endangered, Distribution, Conservation, Endemic

1. Introduction

Kenya is global biodiversity hotspot rich in botanical resources, many which are economically important. Approximately over 8000 vascular plants are estimated to occur in Kenya, out of which 8-10% is considered endemic [1]. Over 80% of endemic species are mainly found in Coastal Forests of Eastern Africa Hotspot (Kenyan Coast) and in isolated Eastern Afromontane Hotspot afro-montane forests (Kenya Mountainous ecosystems). Botanic resources however continue to be threatened by human disturbances as a result of unsustainable human activities such illegal logging and excision of forested ecosystems to give way to other land uses systems such as agriculture, economic development [2]. Changing climate regimes are further predicted to affect species distribution and cause population declines and regional extinctions especially for populations that cannot adapt easily to changing environmental conditions [3]. Currently, about 258 plant species are threatened with extinctions in Kenya and about 6 extinctions have been reported [4].

Endemic species with restricted geographic ranges and specific habitats tend to be most vulnerable to extinction. Their existence is further aggravated by lack of information regarding their population, distribution, ecology and economic value is needed to guide in their conservation. In Kenya, about 392 plant species are recognized as national endemics and about 336 species are highlighted as regional endemics [1, 5]. To date, very little information exist about these species and their conservation needs.

Croton alienus Pax 1909, is among the endemic species in Kenya currently threatened with extinction [6, 7, 8]. Although other *Croton* species in Kenya (*C. megalocarpus, C.*

macrostytus) have been receiving tremendous concern due to their role in provision of fuel wood, medicine and biofuel [9], *Croton alienus* still remains unknown despite it being classified as endangered according to IUCN conservation criteria [7, 8]. To date the species is only known to occur in central highland of Kenya with few populations introduced in Kakamega forest in western Kenya [7]. Most of the biological traits and ecology of *Croton alienus* remain unknown. Any information exists about the species deal only with its descriptions and possible medicinal properties [10, 11]. The species remain poorly studied and is among the less known *Croton* species in Kenya. Literally no information exists about its rate of growth, its reproductive biology, nutrient requirements and distribution patterns. Although there were earlier efforts to raise *C. alienus* seedlings [12], the sustainability of such program are still not known. There is an urgent need to understand its population density, distribution and its real threats to decisively advice on it conservation strategies and provide information for updating of IUCN conservation status.

This review was conducted to contribute towards the conservation of endangered *Croton alienus* by enhancing knowledge and understanding of its population, distribution and conservation status that will aid in development of tools necessary for their sustainable management and conservation purposes. The specific objectives of this review were to identify presence, population density, habitat range, ecology, economic value, current threats and current conservation of the *Croton alienus* in Kenya. The study further hoped to determine distribution pattern of the *Croton alienus* species in Kenya, and propose in-situ and ex situ research and conservation strategies for *Croton alienus*.

2. Methodology of Review

The study involved screening of herbarium specimen at East Africa Herbarium and desktop review of published & unpublished literature articles using internet-based scientific search engines such as ISI web of Science, Scopus and Google Scholar. *Croton alienus* name was used as the major keywords in searching the major databases. Articles documenting taxonomy, abundance, diversity, ecology, distribution, economic importance (ethnobotanical studies) and conservation status (in-situ or ex-situ) were given greater priority. Additional literature, including pre-electronic literature such as dissertations, theses, and other grey materials in East Africa Herbarium were also consulted. International databases were also consulted such as Global Biodiversity Information Facility database

3. Results and Discussions

3.1. Studies on Croton alienus

Literature overview in this study has showed a poor knowledge of endangered *Croton alienus* considering only few studies are carried out (Table 1). Only 6 publications with *Croton alienus* species were documented. The majority of these studies focused on plant diversity, where *Croton alienus* was recorded in the checklist of species [13], with only two studies that focused on analyses of phytochemicals compounds found in *Croton alienus* [9, 14]. There were no studies that focused conservation status of a species, hence on ecological data was found. This indicates urgent need for studies in this endangered species to aid in its conservations.

Screening of herbarium at EA herbarium specimen revealed 39 specimens of *Croton alienus* which were collected between 1909 and 2010 (Table 1). The specimen biodata contained name of region where it was located, geographical data (latitude, longitude and altitude) and classification information. No ecological data and socio-economic information about the species were recorded in the species biodata.

Screening of international databases revealed presence of 18 specimens collected in Kenya (Global Biodiversity Information Facility database) between 1905 and 1941. The database provided information concerning species classification details, geographical data (latitude, longitude and altitude), date of collection and collectors' information. Information related to ecology and conservation details was also absent.

Table 1. *Records of Croton alienus species in Kenya.*

Country	County	Forest	Altitude	Density	Reference/Collector
Literature review					
Kenya	Kiambu	Bob Harries Estate	1520	nd	Malombe and Mutanga, 2004, Polhill and Smith, 1987
	Nairobi	Karura forest,	1778	1 Individual Ha^{-1}	Nyambane et al 2016, Polhill and Smith, 1987
		Ngong forest,	1707	nd	Nyambane et al 2016; Ndunda 2014
		Arboretum forest		nd	FONA 2008
	Nyeri	Mt. Kenya forest	1525-1825	nd	Polhill and Smith, 1987
	Kakamega	Kakamega forest	1500-1700	nd	Fisher et al 2010; Polhill and Smith, 1987
Herbarium specimen at East Africa Herbarium					
Country	County	Forest	Altitude	Density	Specimen collection date
Kenya	Kakamega	Kakamega forest	1524	nd	1909
	Kiambu	Kamiti forest reserve	1493-1707	nd	1905-1996
	Kwale	Kaya Kinondo forest	1646-1707	nd	2010
	Nairobi	Karura forest, Nairobi city park		nd	1930-1997
	Nyeri	Mt. Kenya forest	2000	nd	1930-1988
Equatorial Guinea	Bioko	Moraka North Trail.	15	nd	2009
Madagascar	Masoala Peninsula	Ambanizana Hill	350-550	nd	1992

Country	County	Forest	Altitude	Density	Reference/Collector
Global Biodiversity Information facility (GBIF) Database					
Country	County	Forest	Altitude	Density	Specimen collection date
Kenya	Samburu	Sera Conservancy	1850-3200	nd	Darcy WG, 1905
	Meru	Mt. Kenya forest		nd	Balbo PG, 1928, Lawton 1973
	Laikipia	Mt. Kenya forest		nd	Thomas 1975
	Nyeri	Aberdares forest		nd	Balbao, 1929
	Nairobi	Mt. Kenya forest	2000	nd	Beentje HJ, 1988
		Ngong forest	1707	nd	Battiscombe G,
		Karura forest	1630	nd	Gillet JB, 1930
	Kakamega	Kakamega forest	1524	nd	Adam, 1909
	Kiambu	Aberdares forest		nd	Stuhlmamn, 1905
		Cultivated land	1829	nd	Armstrong K and Bally PR, 1941

3.2. Taxonomy and Description of Croton alienus

Croton alienus is a species in *Croton* genus, the largest genus in Euphorbiaceae family with around 1,300 species distributed in tropical and subtropical regions of both hemispheres. The genus was given name "*Croton*" due to thick smooth seeds, a common feature in Crotonoideae sub-family [15]. There are around 124 species of *Croton* in Africa, and about 114 native species in Madagascar alone [16]. In Kenya, *Croton* genus has fourteen (14) native species and one (1) exotic species [1, 17]. For the 14 species that are native to Kenya, only three species (*Croton megalocarpus, Croton macrostytus* and *Croton dichogamus*) have widespread distribution throughout the Kenya. The three species occur in almost all early administrative division of Kenya and seven plant distribution regions (K1–K7) according to Flora of Tropical East Africa, FTEA (Table 2) [17]. The species are also widely distributed across African countries. *Croton bonplandianus* Baill is the only exotic species, introduced from Australia. The species is only found only along the coastal regions (K7 regions)

Croton alienus is the only Croton species shown to be endemic to Kenya. *Croton alienus* was first classified in 1909 as Mildbraedia balboana Chiov. The species was later moved to *Croton* genus by Pax (1909). The taxonomic features used to delineate it from other Croton species are described in details in Flora of Tropical East Africa [17]. Briefly the species is a monoecious or occasionally dioecious moderate sized tree shrub or small to large tree of about 4.5m. The young twigs are evenly or sparingly scurfily stellate-pubescent while older twigs have greyish brown. Leaves are silvery, white shiny on the underside which turns orange-red with age. Leaves petiole are about 0.2–2.4 cm long, evenly to sparingly scurfily stellate-pubescent. Leaf blade is oblong, elliptic-oblong, elliptic or elliptic-lanceolate. Stipules are linear, glabrous and subpersistent. The flowers are greenish white. C. alienus male flowers have 3-4mm pedicels, sparingly stellate-pubescent, calyx 5-lobed and the lobes broadly ovate while female flowers have 4-5mm pedicels which are stouter than the male pedicels, evenly to sparingly stellate-pubescent; 5-sepals and broadly ovate (3 mm long and 2.5 mm) wide. Inflorescences are racemes terminal, subterminal or pseudaxillary. Fruits are trilobed-ellipsoid, 1 cm long and 0.8 cm wide, septicidal, very sparingly stellate-pubescent or almost glabrous, green at first, becoming dark red or black when ripe. The seeds are reddish brown streaked with buff, having a compressed-ellipsoid (8 mm long and 4 mm wide) in shape.

Table 2. *Croton species, distribution, altitude and habitat in Kenya according to Flora of Tropical East Africa (Polhill and Smith, 1987).*

Species	Origin	Distribution in Kenya	Altitude	Habitat	Other Countries
Croton pseudopulchellus Pax	Native	K1, K6, K7	0-1800	Dry evergreen forest, deciduous woodland, bushland, thicket and secondary regrowth	Tanzania, Mali, Nigeria, Somalia, Angola, Zambia, Zimbabwe, Mozambique, south Africa
Croton zambesicus Muell	Native	K2	750-1600	Wooded grassland on Rocky hills, Riverine, Poor swallow soils	Uganda, Gambia, Nigeria, Sudan, Ethiopia, south Africa, Angola, Mozambique
Croton dichogamus Pax	Native	K1, K2, K3, K4, K5, K7	550-2000	Dry forest, bushland, thicket, rocky ground and porous soil	Uganda, Tanzania, Rwanda, Ethiopia
Croton menyhartii Pax	Native	K1, K4, K7	0-1300	Deciduous bushland and thicket	Tanzania, Angola, Namibia, Ethiopia, Somalia, south Africa
Croton somalensis Vatke & Pax	Native	K1, K6	400-1400	Lava Ridges, Limestone slopes in *Acacia* and *Commiphora* deciduous bushland	Somalia, Ethiopia
Croton megalocarpus Hutch	Native	K1, K3, K4, K5, K5, K7	700-2400	Evergreen forest	Uganda, Tanzania, Zaire, Rwanda, Burundi, Zambia, Malawi, Mozambique
Croton megalocarpoides Friis & Gilbert	Native	K1, K7	5-50	Semi-evergreen forest, Bushland, Rock outcrops and hills where water collects	Somalia
Croton scheffleri pax	Native	K1, K4	800-2300	Bushland, Thicket, Rocky places, poor soil, Riverine	Tanzania, Zambia, Malawi
Croton schimperianus	Native	K1	740-1370	Lower Montane bushland	Ethiopia, Somalia

Species	Origin	Distribution in Kenya	Altitude	Habitat	Other Countries
Muell					
Croton polytrichus Pax	Native	K6	300-160	Dry evergreen forest, Thicket, Woodland, Rocky Hills, Riverine	Tanzania, Sudan, Zambia
Croton macrostachyus Del.	Native	K1, K2, K3, K4, K5, K7	200-2300	Secondary forest, Forest edges, Along rivers, Around lakes, Near forests	Uganda, Tanzania, Guinea, Ethiopia, Angola, Zambia, Malawi, Mozambique
Croton talaeporos A. R-Sm	Native	K7	0-100	Coastal bushland, Wooded grassland	Somalia
Croton sylvaticus krauss	Native	K4, K5, K6, K7	60-1800	Secondary forest, forest edges, along rivers, around lakes	Uganda, Tanzania, Guinea, Ethiopia, Zaire, south Africa
Croton alienus Pax	Native	K4, K5	1525-1825	Upland evergreen forest	
Croton bonplandianus Baill	Exotic	K7	500	Ruderal	Australia, Bolivia, Brazil, Argentina

K1–K7 indicates plant distribution regions in "Flora of Tropical East Africa, FTEA " (Polhill and Smith, 1987).

3.3. Distribution and Population Status of Croton alienus

Croton alienus is among the least known species in Kenya. The species occur in Kiambu, Nairobi, Nyeri, Meru, Kwale, Samburu and Kakamega counties (Table 3; Figure 1). Based on few studies found in this study, our results confirm *Croton alienus* is mainly restricted central highland regions around humid, evergreen mountainous forests [17]. The species was mainly found in areas such as natural forest remnants around private land (Bob Harries Estates) in Ruiru, Kamiti forest reserves, Ngong forest, Karura forest, Arboretum forest, Mt. Kenya forest and Aberdares forests (Table 2) [9, 13, 17, 18, 19, 20, 21]. The altitude range of this species in central highland was mainly 1500-2000 m above sea level (Table 2). In this region, the species is shown to grow often in association with *Brachylaena hutchinsii* Hutch and *Croton megalocarpus* Hutch [22].

Table 3. *Phytochemicals recorded in Croton alienus.*

Compound			Literature
Lipids	Alienusolin	4α -deoxyphorbol ester	
Alkaloids	Glutarimide alkaloid	Crotonimide C Julocrotine	
Terpenoid Compounds	Methylcyclohexane	Crotepoxide (antimicrobial & nematicidal) Monodeacetyl crotepoxide Dideacetylcrotepoxide β-senepoxide α-senepoxide (+)-(2S, 3R-diacetoxy-1-benzoyloxymethylenecyclohex-4, 6-diene 4-hyroxy-1-methylproline (antimicrobial & nematicidal)	Ndunda et al 20143 Langat et al 2015 Chhabra et al., 2007
	Pentacyclic triterpenoid	Acetyl aleuritolic α, β-unsaturated phytosterol (24-ethylcholesta-4, 22-dien-3-one)	
Phenolic Compounds	Benzoic acid esters	Benzyl benzoate	

There is also possibility of the species occurring in other regions apart from central highland (K1 and K7) which were not documented earlier. Screening of Herbarium specimen at East Africa Herbarium showed occurrence *Croton alienus* in Kwale documented in year 2010 (Table 1). Global Biodiversity Information Facility database revealed two records of *Croton alienus* specimen in Samburu County, mainly from Mt. Nyiro forest and Sera conservancy documented in year 1905 and 1905 respectively. From the specimen bio-data, it is not clear whether *Croton alienus* is a new introduction to these areas or is a native species in the region. The last report of *Croton* species in Kenya and East Africa is Flora of Tropical East Africa of 1987 [17]. Since then, new discoveries, records have been found and proposed. This suggests need for detailed studies to verify occurrences of *Croton alienus* in this region and other similar regions in Kenya.

Surprisingly, there were also records of *Croton alienus* specimen from Madagascar and Equatorial Guinea (Figure 1). Screening of herbarium specimen at East Africa Herbarium revealed *Croton alienus* specimen collected from Equatorial Guinea and Madagascar in year 2009 and 1992 respectively (Figure 1). *Croton alienus* in Madagascar and Equatorial Guinea were collected in low altitude areas below 550m above sea level (Table 2). It's not clear yet whether the species collected in these countries are native to the region or new introductions. Current review of *Croton* species in Madagascar did not show presence *Croton alienus* (Berry et al., 2017). Similarly major checklists of Croton species in Equatorial Guinea don't also show presence of *Croton alienus species* [23, 24]. Our results suggest *Croton alienus* may not be endemic to Kenya. There is also possibility of problematic classification within *Croton* genus with many poorly known species. Recent study in West Africa has erected a new genus *Karima* following lack of diagnostic characters in *Croton scarciesii* from genus Croton [25]. This

suggests need for updated information regarding *Croton* species in Africa. A thorough phylogenetic-based revision of *Croton* (Euphorbiaceae) in Africa is thus needed.

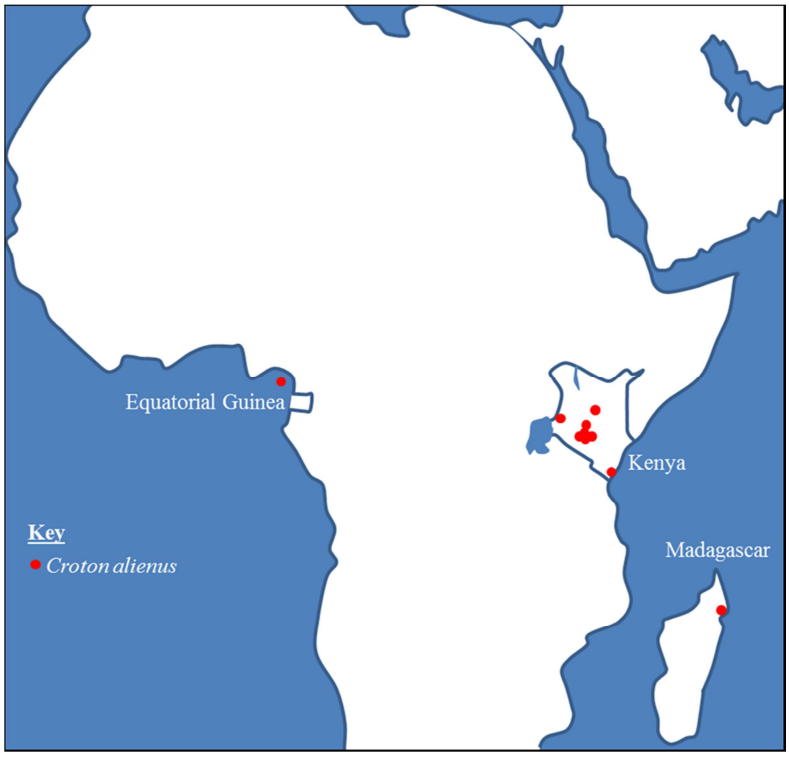

Figure 1. *Distribution of Croton alienus.*

Information concerning *Croton alienus* ecology and density was missing from reviewed papers, screened herbarium specimen and databases. Only one study recorded population status of *Croton alienus* in Karura forest in Nairobi region [21]. The *Croton alienus* density in Karura forest was very 1 tree per hectare, indicating possibility of finding approximately 1063 *Croton alienus* trees in entire forest. Population density in all other forest was missing. There was also a worrying trend of missing *Croton alienus* in plant species checklist from recent studies in forest where the species was previously documented. Study in Mt. Kenya showed no presence of *Croton alienus* in this forest [26]. Another study in Ngong and City Park forests in Nairobi did not show presence of *Croton alienus* [21]. Taking into consideration that many records of *Croton alienus* are very old (1905-1941), and geographic coordinate system (GPS) of areas it was collected falls within cultivated land there urgent need for detailed field studies to confirm species existences in these regions.

3.4. Economic Importance

Members of the genus *Croton* are well known of their medicinal properties. In Kenya, *Croton* species have been used in herbal medicine for many applications. For example the decoction of the bark, roots and leaves of *Croton* species in Kenya have been used to treat stomach problems, malaria, pneumonia, worms, whooping cough, syphilis, anthrax cancer, constipation, diabetes, digestive problems, dysentery, external wounds, fever, hypercholesterolemia, hypertension, inflammation, pain, ulcers and weight-loss and snakebites [20, 27, 28, 29]. Apart from medicinal uses, *Croton* species in Kenya have been used as fire-wood, in agroforestry, for mulching, in charcoal production and as wind breaker. Seeds of *Croton megalocarpus* have also been use in production of biofuel due to high oil content (30%). *Croton alienus* is among the least known *Croton* species in Kenya, hence very few economic importance of *Croton alienus* are documented. Literature reviewed revealed only ethno-medicinal use of *Croton alienus* among Kikuyu community in central Kenya. In this region *Croton alienus* was used traditionally to treat body weakness [10]. Leaves and stem pieces are also boiled and mixed with soup to cure intestinal worms and gouts [13].

3.5. Phytochemistry of Croton alienus

Due to wide ranges of ethnomedicinal uses of the *Croton* species, several studies have been conducted to investigate their phytochemical constituents. This is being dictated by need to develop new pharmaceutical drugs and agrochemicals with ability to overcome multi-drug resistance experienced amongst many pathogenic microbes in humans, animals and plants. Plant phytochemicals are produced during plant metabolism to either enhance plant growth or aid in plant growth and development. Primary metabolism mainly produces chemical compound such as nucleic acids, amino acids, proteins, carbohydrates and organic acids, lipids, and natural products whose role is to enhance and sustain plant growth. On the other hand, secondary metabolism produces chemical compound such as like

alkaloids, terpenoids, saponins and phenolic compounds, whose role is to aid plant development by protecting plants against pests and pathogens (microbial infections or infestations, pests, competitors or predators), sustaining pollinations and increasing plant tolerance towards worsening climatic conditions and environmental pollutants [30]. These chemicals occur naturally in leaves, stems and roots of plants.

Generally, there are six major categories phytochemicals (carbohydrate, lipids, phenolics, terpenoids, alkaloids and nitrogen-containing compounds) that have been classified based on their chemical structures and characteristics (Table 4) [31]. Phytochemicals with ability to influence physiological or cellular activities in animals or humans when consumed are called bioactive phytochemicals, and are associated with theurapetic properties [32]. Chemical compounds like phenolic compounds, terpenoid compounds and alkaloids are known to have medicinal properties. Terpenoids are shown to exhibit pharmacological activities against inflammatory, cancer, malaria, cholesterol synthesis, virus and bacterial activities.

Table 4. *Major Phytochemicals in plant species.*

Phenolic	Alkaloids	Terpenoids	Nitrogen	Organic acids/lipids	Carbohydrates
Flavonoids: Anthocyanins, Flavonols, Flavanols, Dihydroflavonols, Flavones, Isoflavonoids, Flavanones, Dihydrochalcones Phenolic Acid Hydrobenzoic acid Hydroxycinammic acid Phenols Alkylphenols, Methoxyphenols Phenylpropanoids Benzodioxoles Curcuminoids Hydroxyphenyl-propenes Quinones Benzoquinones, Naphthoquinones, Anthraquinones Coumarins Coumestans Furanocoumarins Lignans Stilbenoids Xanthones	Betalain Alkaloids Betacynins Betaxamthins Indole Alkaloids Erforlines Yohimbans Tryptolines (β-arbolines) Betaxamthins Others Pyridine Indolizidine Pyrrolidine Quinoline Isoquinoline Steroidal Tropane	Monoterpenoids Phenolic terpenes Triterpenoids Phenolic terpenes Saponins Phytosterols Tetrarpenoids Carotenoids Others Sesquiterpenoids Diterpenoids	Amines Benzylamines, Phenylethylamines Tryptamines Glucosinolates Aliphatic Aromatic Purines Xanthines Others Indole alcohols Cyanogenic glycoside	Short-chain Aldonic acids Aldaric acids Fatty acid Omega-6-fatty acids Alkanes & related hydrocarbons Waxes Sulfur Thiosulfinates	Monosaccharides Disaccharides Oligosaccharides Sugar-alcohol

Croton species are shown to be rich in chemical compounds (diterpenoids, alkaloids, latex) which are usually associated with medicinal properties [27]. Most of these compounds are shown to have anti-oestrogen, anti-cancer, anti-hypertensive, anti-inflammatory, antimalarial, antimicrobial, antispasmodic, antiulcer, antiviral and myorelaxant properties [27]. Phytochemical screening of *Croton alienus* leaves and roots revealed the presence of 14 compounds (Table 3) [10, 11, 14]. These included presence of alkaloids, Phenolic compounds (flavones, flavonoids, tannins), glycosides, terpenoids (saponins), carbohydrates (reducing sugars), sterols, and terpenoids in *Croton alienus* leaves and roots (Table 4). The root and stem bark aqueous extracts were shown to be active against *Candida albicans* and *Aspergillus niger*. *Candida albicans* growth was inhibited at very low concentration (25 mg / mL). The leave extracts of *Croton alienus* inhibited growth of *Leishmania donovani* when applied at rate of 80 µg / mL. These demonstrate economic importance of *Croton alienus* that may be explored to support its domestication and conservation.

3.6. Threats and Conservation Status

Un-sustainable human activities are major threat of *Croton alienus* in its natural conditions. Data in this study show many records of *Croton alienus* are very old (1905-1941), and geographic coordinate system (GPS) of areas it was collected falls within cultivated land or urban centers (Table 4). This means most of its population has been cleared to give way to agriculture necessitating urgent need for detailed field studies to confirm species existences in these regions. Nearly all forested ecosystems in Nairobi regions though under protection remain highly threatened by development, encroachment, pollution and land grabbing. Other forested ecosystem within central and western Kenya (Mt Kenya forest, Arbedares, Kakamega forest) though have received considerable resources and efforts to improve their management are still facing tremendous threats and pressures from local community living adjacent these forest. Habitat disturbances and degradation associated with wildlife poaching for meat, illegal logging for timber, forest fires,

invasive species, illegal water abstraction and human-wildlife conflict are cited as major human activities threatening these forests and biodiversity residing in them [7, 8]. Over the past two decades more than 30% of natural forests have been lost to illegal logging, charcoal burning and excision of land to give way to other land use systems (plantation forest and Nyayo tea zones). These activities are linked to scarcity of natural resources such of water and agricultural land, land degradation, poverty, rapid human population increase and weak management systems. How such activities have influenced *Croton alienus* population still remains unknown.

Table 5. *Major threats of Croton alienus in Kenya.*

County	Ecosystem	Latitude	Longitude	Altitude	Year Collected	Current status
Samburu	Sera Conservancy	1	38	1850-3200	1975	Forest
Laikipia	Mt. Kenya forest	0.01	36.86	nd	1975	Cultivated
Kakamega	Kakamega forest	0.28	34.75	1524	1909	Cultivated
Meru	Mt. Kenya forest	0.05	37.65	nd	1929	Cultivated
	Mt. Kenya forest (Ngare Ndare forest)	0.17	37.45	nd	1973	Forest edges
Nyeri	Mt. Kenya forest	-0.33	37.05	2000	1988	Forest
	Aberdares forest	-0.42	36.95	nd	1929	Urban area
Kiambu	Aberdares forest - Gatamaiyu forest	-0.92	36.67	nd	1905	Forest
	Kiambu, cultivated land	-1.18	36.83	1829	1941	Cultivated
Nairobi	Karura forest	-1.25	36.83	1630	1930	Forest
	Ngong forest	-1.32	36.73	1707		Forest

nd = not determined

3.7. Climate Change

Apart from human activities, climate change is also expected to cause tremendous decline to *Croton alienus*. From our results, *Croton alienus* occurs mainly in central regions within an altitude range of 1200 to 2000m above the sea level. Although *Croton alienus* was documented in Kwale and Samburu County, recent studies within these regions have not shown its presence in forests ecosystems [33, 34, 35], and hence very little information exist to justify its natural occurrences in these sites. There is possibility of *Croton alienus* introduction in these sites but reasons for such introduction remain unknown since *Croton alienus* remain little known. There is therefore need for detailed studies to survey occurrences of *Croton alienus* in these regions. Meanwhile, going with its natural area of occupancy in central, Nairobi and western Kenya regions mainly in mountainous forest ecosystem there is possibility of tremendous effect of climate change on its population. Global climate warming is causing upward relocation of species along elevational temperature gradients [36, 37], resulting to population and distribution range decline as the total area available at a given altitude decreases with elevation [38]. This effect is shown to affect endemic species with narrow altitude ranges [39]. Since *Croton alienus* in its natural condition is confined to mountainous ecosystems it population may be reduced significantly by temperature increases. There is thus need for studies to unveil whether temperature increases as a result of global climate warming has any negative implication on *Croton alienus* distributional range and population status.

3.8. Conservation Status

Croton alienus is currently classified as endangered according to IUCN classification criteria due to its restricted area of occupancy [7, 8]. In-situ conservation measures such as the protection and restoration of natural habitats are the best methods of preserving biological diversity [40, 41]. From this study only small population are currently being protected in Mt. Kenya, Aberdares and Kakamega Forest [7]. The remaining population remains unprotected and is prone to extinctions following continued practices of unsustainable human activities in its habitat. Due to its narrow altitude range, the species may be also facing population and distribution range decline from continued global climate warming. There is there need for additional in-situ conservation measures to ensure species protections. Use of plant micro-reserves and species recovery programs (e.g. restoration programs) to boost current in-situ conservation strategies can be explored.

Ex-situ conservation strategies undertaken for *Croton alienus* include seed collection, storage in seedbank and rising of seedlings for restoration programs [12]. However the sustainability of such programs is not well documented. Storage of plants seeds in genebank is one of the most effective ways for ex-situ conservation plant species. Genebank ensures large amount of genetic materials are protected in a small space for use in future research, restoration programs and for minimizing risk of genetic damage [42]. To maintain viable seeds, seed viability tests are required to ensure seed stored in genebank can produce plants if sown in the field. It well known seeds viability declines as seeds ages, and is usually important to know when to regenerate the accessions. Current there is no literature showing duration for seed viability decline for *Croton alienus*. Earlier seed viability tests had shown loss of seed viability resulting in germination difficulties within six months of storage (Personal communication). Worse still, information regarding *Croton alienus* restoration programs is still lacking. This suggests need for further ex-situ conservation strategies including seed collection, seed storage, viability tests and propagation of seedling. Immediate restoration programs as an alternative way to

prevent immediate extinction is required. There is also need to explore domestication of *Croton alienus* for medicinal purpose. In this study we have shown presence of over ten phytochemical compounds with antibiotic properties. We have also shown its herbal usage among Kikuyu community.

4. Conclusions

Results of this study indicate that *Croton alienus* is among the least known endangered species in Kenya, with restricted area of occupancy and narrow altitude range restricting it to forests in central Kenya (Aberdare forest, Mt Kenya forest), Nairobi region (Karura forest, Ngong forest, Arboretum) and Western Kenya (Kakamega forest). Although *Croton alienus* has been classified as endemic to Kenya, result of this study suggest it may be found in other parts of Africa following its documentation in Madagascar and Equatorial Guinea. They may also suggest problematic classification in genus *Croton* in Africa highlighting the need for updated information and phylogenetic-based revision of *Croton* (Euphorbiaceae) species in Africa. Very little information existed on ecology and density of *Croton alienus*. Similarly only very small population of *Croton alienus* may be protected in-situ. Many records of *Croton alienus* are very old (1905-1941), and geographic coordinate system (GPS) of areas it was collected falls within cultivated land or urban centers. This suggests urgent need for research and alternative in-situ conservation strategies such as plant micro-reserves and species recovery programs (e.g. restoration programs) to boost current in-situ conservation strategies and ensure its effective protection in the wild. Ex-situ conservation strategies applied previously included seed collection, storage in seedbank and rising of seedlings for restoration programs. However sustainability of such initiatives remains uncertain. There is no information regarding regeneration of genebank accessions, yet the *Croton alienus* seeds viability is thought to be extremely low (less than six months). This study recommends urgent ex-situ conservation strategies as an alternative way to prevent its extinction. Domestication of *Croton alienus* for medicinal purpose can be explored. *Croton alienus* has over 10 biochemical compounds with anti-oestrogen, anti-cancer, anti-hypertensive, anti-inflammatory, antimalarial, antimicrobial, antispasmodic, antiulcer, antiviral and myorelaxant properties which can be tapped to aid its domestication and conservation. The antibiotic properties were shown to be effective against *Candida albicans* and *Leishmania donovanii* micro-organisms. Although effect of climate change on its distributions is not yet documented, this study further highlights need for development of conservation measures for endemic species with restricted geographic ranges and specific habitat need in awake of climate change to prevent their extinction.

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