INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 9, No. 1, p. 182-191, 2016

RESEARCH PAPER OPEN ACCESS

# Morphological characterization and distribution of cactus species (Cactaceae) in arid and semi-arid lands of Kenya

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**Article published on July 31, 2016**

**Key words:** Diversity, Cactus, Distribution, *Opuntia*, Morphological characterization.

## Abstract

Cactaceae family is an important plant of Arid and Semi-Arid Lands (ASALs) of the world. It is useful for ornamental (*Cereus peruvianus and Thrixanthrocereus blossfeldiorum*), food, fodder and industrial production (*Opuntia spp.*). The objective of this study was to characterize and determine the distribution of cactus species in two ASAL zones of Kenya (Rift Valley and Eastern).Sixty nine distinct populations of cactus were characterized *in-situ* using a list of descriptors by the International Union for the Protection of New Varieties of Plants (UPOV). Results indicated that eight species namely, *Opuntia exaltata, Opuntia monacantha, Opuntia ficus-indica, Opuntia stricta, Thrixanthrocereus blossfeldiorum, Euphorbia abyssinica, Euphorbia ingens* and *Cereus peruvianus* were present in Kenya. *Opuntia ficus-indica* was the most diverse and was found in four of the five counties studied. *Euphorbia abyssinica* was found in four counties while *Opuntia stricta* and *Thrixanthrocereus blossfeldiorum* were found in a single county each. The results revealed morphologically a significant diversity among cactus species in Kenya. Further research is needed through molecular characterization and to cover the entire country to identify other species available in these areas and their mode of distribution as well as their productivity to influence the choice species for utilization.

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**Introduction**

Cactuses are xerophytes that are known to grow in arid and semi-arid lands (ASALs). They are adapted to these environments by having features such as shallow root systems, enlarged stem cortical layers, enlarged piths, succulent stems that live for long and able to photosynthesize using the crassulacean acid metabolism (CAM) photosynthesis (Edwards and Donoghue, 2006).

The Cactaceae family has four subfamilies namely; Maihuenioideae with 2 species, Pereskioideae with 17 species, Cactoideae containing 1222 species and Opuntioideae with 186 species (Edwards and Donoghue, 2006; Griffith, 2004; Oldfield, 1997; Ortega-baes *et al*., 2010). The Opuntia species, commonly found in agricultural systems, belong to the Cactoideae.

Cactus species found in Kenya and many parts of the world are native to Latin America including Bolivia, Peru, Argentina and Chile (Defelice, 2004).The highest diversity of cactus in the Americas is found in Mexico (Ortega-Baes and Godínez-Alvarez, 2006).

The Opuntia species has been domesticated in agricultural systems in some parts of the world, for example South Africa, Italy Mexico and Israel, and its production commercialized for various purposes (Caloggero and Parera, 2004). The species are also important for subsistence economies (Feugang *et al*., 2006) where they are utilized as fodder (Kang'ara and Gitari, 2008; Tibe *et al*., 2008), fruit, vegetable, medicine, production of cochineal (Ervin, 2012); food products including beverages, juices, liquid sweeteners and jams (Yeddes *et al*., 2013). The crop is also used to make fences/hedges (Khalafalla *et al*., 2007), preparation of medicinal products and the spines may be used as toothpicks (Tibe *et al*., 2008). It is a source of income for some families in Ethiopia (Ervin, 2012).

About eighty nine percent of Kenya's land mass is arid to semi-arid (ASAL) (Mohajan 2014; G.O.K, 2012)with mean annual rainfall between 150-550mm and high temperatures throughout the year.

Cactus species are commonly found in these ASALs which are located in the Eastern, North Eastern and Rift valley regions. The plants are mostly found growing along roads and/or established as life hedges (Tibe *et al*., 2008) in some farms. Kang'ara and Gitari (2008) reported the use of cactus for marking boundaries and for ornamental purposes. The bountiful nutritional benefits of *Opuntia stricta* Haw in Kenya has been described by Kunyanga *et al*., (2014) while Chiteva and Wairagu (2013) documented the benefits of *Opuntia ficus-indica* (L.). Despite this crop's benefits, some communities in Kenya viewed it as a noxious weed that degrades land (Kang'ara and Gitari, 2008).

The rising concern over the unpredictable climatic changes coupled with increasing population pressure on available scarce arable land resource call for diversification in crop production. The evaluation of potential drought tolerant crops, such as the *Opuntia* species in the ASALs of Kenya could be the gateway to achieve this. This is because these species are well adapted for growth under ASAL conditions due to the possession of the CAM metabolism (Tibe *et al*., 2008), high cuticular resistance to water loss and shallow root system (Fischer & Turner, 1978). On the other hand, more people are becoming aware of the benefits of its products beyond its traditional use as boundary markers and ornamental plants and thus its increased utilization as vegetable, food products and other industry uses.

Several Opuntia species have been described morphologically (Gallegos–Vásquez *et al*., 2010). Morphological characterization of germplasm has been suggested to be the first pointer of variability (Chalak *et al*., 2014) that should precede molecular marker assessment (Watson and Eyzaguirre, 2002).

To the best of our knowledge there is no documented information on the morphological characterization of the Cactuses in Kenya. This is the first study in Kenya to describe this variability in Cactaceae in order to foster utilization of the species as a source of human food, animal feed, and for industrial uses, and preserve current genetic diversity of the germplasm in Kenya. The objective was to map out and characterize cactus accessions growing in ASALs of Kenya.

## Material and methods

*Site Description*

The study sites comprised of two zones located in the ASALs of Kenya. The areas were selected in consideration of their climatic conditions and presence of the cactus species. These included the Eastern zone comprising of Machakos and Makueni County, and the Rift Valley zone encompassing Nakuru, Baringo and Laikipia, counties. Twenty eight locations spread over the five counties were identified for the sampling. The counties are located above 1000 m but below 3098 m of altitude and receiving rainfalls of between 150mm and 1800mm (Table 1).

**Table 1.** Specific locations where cactus species were mapped in Kenya.

| S. No. | Species | County | Location | Altitude (m asl) | Longitude | Latitude | Temperature | Rainfall (mm p.a) |
|---|---|---|---|---|---|---|---|---|
| 1. | *Cereus peruvianus* | Machakos | Lukenya 1 | 1000-1600 | 037.04765°E | 01.46028°S | 9.1°-26.7°C | 500-900 |
| 2. | *Thrixanthrocereus blossfeldiorum* | Machakos | Daystar | 1000-1600 | 037.03706°E | 01.47686°S | 9.1°-26.7°C | 500-900 |
| 3. | *Euphorbia abyssinica* | Machakos | Arthi River | 1000-1600 | 037.04729°E | 01.46043°S | 9.1°-26.7°C | 500-900 |
| 4. | *Euphorbia abyssinica* | Machakos | Green park | 1000-1600 | 037.01513°E | 01.46534°S | 9.1°-26.7°C | 500-900 |
| 5. | *Cereus peruvianus* | Baringo | Kures | 1000-2600 | 035.91872°E | 00.08334°N | 10°-35°C | 600-1500 |
| 6. | *Euphorbia ingens* | Baringo | Radat | 1000-2600 | 035.89096°E | 00.05399°S | 10°-35°C | 600-1500 |
| 7. | *Opuntia ficus-indica* | Nakuru | Delamere 1 | 1530-3098 | 036.41130°E | 00.68800°S | 12°-29.3°C | 500-1800 |
| 8. | *Opuntia exaltata* | Nakuru | Naivasha | 1530-3098 | 036.41100°E | 00.68802°S | 12°-29.3°C | 500-1800 |
| 9. | *Opuntia monacantha* | Baringo | Marigat | 1000-2600 | 035.94146°E | 00.38866°N | 10°-35°C | 600-1500 |
| 10. | *Opuntia ficus-indica* | Laikipia | IDP-Wiyumererie | 1500-2611 | 036.65597°E | 00.05776°S | 16°-26°C | 400-750 |
| 11. | *Opuntia ficus-indica* | Laikipia | Matunda | 1500-2611 | 036.67084°E | 00.01241°S | 16°-26°C | 400-750 |
| 12. | *Euphorbia abyssinica* | Laikipia | Nairuti | 1500-2611 | 036.71133°E | 00.14193°S | 16°-26°C | 400-750 |
| 13. | *Opuntia exaltata* | Laikipia | Jikaze | 1500-2611 | 036.61605°E | 00.07926°S | 16°-26°C | 400-750 |
| 14. | *Opuntia monacantha* | Makueni | Utini | 1000-1600 | 037.58617°E | 02.10618°S | 9.1°-26.7°C | 500-900 |
| 15. | *Euphorbia abyssinica* | Makueni | Salama | 1000-1600 | 037.25404°E | 01.83437°S | 9.1°-26.7°C | 500-900 |
| 16. | *Cereus peruvianus* | Machakos | Lukenya 2 | 1000-1600 | 037.06279°E | 01.49396°S | 9.1°-26.7°C | 500-900 |
| 17. | *Opuntia stricta* | Makueni | Sultan Hamud | 1000-2100 | 037.36682°E | 02.00916°S | 12°-28°C | 150-650 |
| 18. | *Euphorbia ingens* | Nakuru | Kiongororia | 1530-3098 | 036.35695°E | 00.56759°S | 12°-29.3°C | 500-1800 |
| 19. | *Opuntia ficus-indica* | Nakuru | Dalmare farm | 1530-3098 | 036.41121°E | 00.68857°S | 12°-29.3°C | 500-1800 |
| 20. | *Cereus peruvianus* | Nakuru | PemaVictorius | 1530-3098 | 036.23124°E | 00.37987°S | 12°-29.3°C | 500-1800 |
| 21. | *Thrixanthrocereus blossfeldiorum* | Machakos | Lukenya | 1000-1600 | 037.04763°E | 01.04763°S | 9.1°-26.7°C | 500-900 |
| 22. | *Opuntia exaltata* | Machakos | Arthi River | 1000-1600 | 036.99327°E | 01.44386°S | 9.1°-26.7°C | 500-900 |
| 23. | *Opuntia monacantha* | Baringo | Marigat | 1000-2600 | 035.97977°E | 00.47060°N | 10°-35°C | 600-1500 |
| 24. | *Opuntia monacantha* | Machakos | Masimba | 1000-1600 | 037.60233°E | 02.15351°S | 9.1°-26.7°C | 500-900 |
| 25. | *Opuntia exaltata* | Nakuru | Kikopei | 1530-3098 | 036.41100°E | 00.68802°S | 12°-29.3°C | 500-1800 |
| 26. | *Opuntia ficus-indica* | Nakuru | Kiongororia | 1530-3098 | 036.41130°E | 00.68800°S | 12°-29.3°C | 500-1800 |
| 27. | *Opuntia ficus-indica* | Machakos | Lukenya 2 | 1000-1600 | 037.04918°E | 01.45531°S | 9.1°-26.7°C | 500-900 |
| 28. | *Opuntia exaltata* | Nakuru | Dalmare farm | 1530-3098 | 036.43187°E | 00.70041°S | 12°-29.3°C | 500-1800 |

*Morphological Characterization*

Field survey and morphological characterization was carried out between February and May of 2014 during the fruit maturity stage of the plants. The survey targeted maximum characterization *in situ* of cactus species in the wild and in farms where they are established as hedges in the two selected ASAL zones in Kenya.

For all identified accessions, three plants with mature fruits and a good canopy were characterized where by, characteristics of plants' growth habits, areoles, stems, cladodes, spines, inflorescence, fruits and seeds were recorded against a descriptor list(UPOV, 2006). The GPS co-ordinates for the characterized materials were recorded (Table 1).

For every sampled cactus plant, three replications of plant height, growth habitus, stem lengths and diameters, areole sizes, cladode lengths and widths, branching angles, corolla colors, fruit colors and sizes, color and length of spines, fruit and pulp color, angle of branches, leaf characters, fruit set, glochids, seed color and number of seeds per fruit were recorded and the mean of each taken as the final reading.

*Data analysis*

The mean ±standard deviations and coefficient of variation for each quantitative trait were calculated using SAS 9.1.3 (Table 4). The normality test was performed using SAS 9.13 for each variable to check if the sample came from a normally distributed population. A hierarchic grouping was done by using the un weighted pair-group arithmetic averages method (UPGMA)(Sokal and Michener, 1958) and then the grouping was represented in a tree dendrogram (Fig. 1).

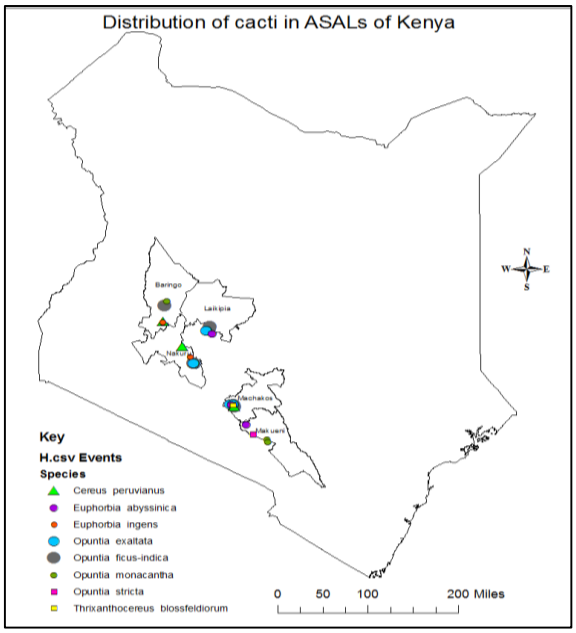


**Fig. 1.** Distribution of *Opuntia* species in Kenya's ASALs

## Results

*Distribution of cactus species in the ASALs of Kenya*

In most cases, cactus species were found growing in rows as fencing/border material in farms, along main roads and some were dispersed intermittently in uncultivated lands.

The distribution of these species in cultivated areas was mostly influenced by human activity in the area of study.

High clonal populations of *Opuntia monacantha* were found in Marigat (Baringo County) both along farm hedges and in uncultivated lands, with some sparsely distributed in Lukenya (Machakos County) and Utini (Makueni County) grown as hedges.

Large clonal populations of *Opuntia ficus-indica* were found in Matunda (Laikipia County) while sparsely distributed near Dalemere farm (Nakuru), Kures (Baringo) Lukenya (Machakos) and Salama (Makueni) in uncultivated areas. A single population of *Opuntia stricta* was only found in Sultan Hamud (Makueni County) while *Thixanthrocereus blossfeldiorum* was found in Lukenya (Machakos County) only. Both species were established as hedges in farms.

Dense hedges of *Opuntia exaltata* were found along farms in Nakuru (Dalemere), Laikipia (Jikaze) and Machakos (Arthiriver) counties. None of the *Opuntia exaltata* was found growing wildly. *Euphorbia ingens* and *Euphorbia abyssinica* were sparsely distributed in uncultivated areas Nakuru, Baringo and Machakos counties. These were also spotted grown as hedges in Nakuru County.

*Cereus peruvianus* was grown as an ornamental plant in Machakos County while in Baringo and Nakuru it was sparsely found either along fences or in uncultivated areas. Table 2 indicates the specific presence of cactus species in the study areas.

*Diversity of cactus species in ASALs of Kenya based on morphological traits*

The characterized accessions were either arborescent or shrubby except for the *Thrixanthrocereus blossfeldiorum* that was columnar. Majority of species had elongated shape (e.g. *Opuntia exaltata*, *Opuntia ficus-indica*) with 32 populations baring round shaped canopies (e.g. *Opuntia monacantha, Opuntia stricta, Euphorbia ingens*). Majority of the Opuntia species stems produced were flattened whereas all the *Opuntia exaltata, Euphorbia ingens, Euphorbia abyssinica* accessions had round shaped stems. *Cereus peruvianus* and *Thrixanthrocereus blossfeldiorum* had ribbed stems.

The diversity of the species was also distinguished by the presence or absence of cladodes. All the *Opuntia* species had cladodes and the rest did not have cladodes. Differences in cladode characteristics among the *Opuntia* species were also noted. *Opuntia ficus-indica and Opuntia monacantha* mainly produced either ovate or elliptic cladodes and only *Opuntia exaltata* bore cylindrical cladodes. Spines were present in all the cactuses but there were no glochids in *Opuntia exaltata* cladodes and the non-opuntia species namely; *Cereus peruvianus, Euphorbia ingens, Euphorbia abyssinica* and *Thrixanthocereus blossfeldiorum*. There were relatively short or no spines on cladodes of very aged *Oputia ficus-indica* species which may be misconstrued to mean they are spineless.

Twenty seven of the 69 populations had white spines (e.g. *Opuntia ficus-indica, Opuntia monacantha*), *Cereus peruvianus* produced brown spines and *Opuntia exaltata* had either golden or white spines or the difference being location based and the rest had either black or grey spines.

Six corolla colors were recorded namely; white, pink, yellow, cream, orange and yellow with purple strips. All the *Opuntia exaltata* accessions had pink flowers, while orange flowers were produced by *Opuntia ficus-indica*. *Opuntia stricta* produced yellow flowers and the *Opuntia monacantha* had yellow flowers with purple strips. *Thrixanthocereus blossfeldiorum* and *Euphorbia spp*. had cream flowers while *Cereus peruvianus* and had white corolla (Table 2).

Most accessions' fruits produced were oval in shape with the exceptions in *Opuntia stricta, Euphorbia abyssinica, Euphorbia ingens* that produced globuse fruits and *Cereus peruvianus* that had elliptic fruits. None of the *Opuntia exaltata, Euphorbia ingens, Euphorbia abyssinica and Cereus peruvianus* accessions had fruit glochids whereas the rest produced fruits with glochids. Mature fruits with purple coloration were produced by *Opuntia monacantha, Opuntia stricta, and Opuntia ficus-indica*. All the *Opuntia exaltata* produced light green fruits, *Cereus peruvianus* violet-red fruits and *Thrixanthrocereus blossfeldiorum* red fruits. The pulp coloration of the fruits was similar to the mature fruit rind color except for *Cereus peruvianus* that has white pulp (Table 3).

**Table 2**. Distribution of cactus species in ASALs of Kenya.

| Location | Nakuru | Baringo | Laikipia | Machakos | Makueni |
|---|---|---|---|---|---|
| Species | | | | | |
| *Opuntia monacantha* | | ■ | | ■ | ■ |
| *Opuntia ficus-indica* | ■ | ■ | ■ | ■ | |
| *Opuntia exaltata* | ■ | | ■ | ■ | |
| *Opuntia stricta* | | | | | ■ |
| *Thrixanthrocereus blossfeldiorum* | | | | ■ | |
| *Euphorbia abyssinica* | | ■ | ■ | ■ | ■ |
| *Cereus peruvianus* | ■ | ■ | | ■ | |
| *Euphorbia ingens* | ■ | ■ | | | |

**Table 3**. Corolla color and fruit characteristics.

| Species | Corolla color | Fruit shape | Fruit glochids | Mature fruit color | Pulp Color |
|---|---|---|---|---|---|
| *Opuntia monacantha* | purple stripped yellow | Ovoid | Present | Purple | purple |
| *Opuntia ficus-indica* | Orange | Ovoid | Present | Yellowish | orange |
| *Opuntia exaltata* | Pink | Ovoid | Absent | Green | green |
| *Opuntia stricta* | Yellow | Globuse | Present | Purple | purple |
| *Euphorbia abyssinica* | Cream | Globuse | Absent | Purple | purple |
| *Cereus peruvianus* | White | Elliptic | Absent | violet-red | white |
| *Euphorbia ingens* | Cream | globuse | Absent | Purple | purple |
| *Thrixanthrocereus blossfeldiorum* | Cream | Ovoid | Present | Red | red |

**Table 4.** Descriptive Statistics of the Quantitative characters of the identified cactus species.

| Species | | N | Minimum | Maximum | Mean | | Std. Deviation |
|---|---|---|---|---|---|---|---|
| | | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic |
| *Cereus peruvianus* | Plant height | 9 | 350.00 | 580.00 | 440.2222 | 27.04255 | 81.12764 |
| | Spine size | 9 | 3.00 | 5.60 | 4.1667 | .27386 | .82158 |
| | Cladode length | None | - | - | - | - | - |
| | Cladode width | None | - | - | - | - | - |
| *Euphorbia abyssinica* | Plant height | 8 | 470.00 | 650.00 | 530.3750 | 21.08989 | 59.65122 |
| | Spine size | 8 | .40 | 1.20 | .8375 | .09625 | .27223 |
| | Cladode length | None | - | - | - | - | - |
| | Cladode width | None | - | - | - | - | - |
| *Euphorbia ingens* | Plant height | 5 | 500.00 | 570.00 | 522.4000 | 12.31909 | 27.54632 |
| | Spine size | 5 | .80 | 1.00 | .8800 | .04899 | .10954 |
| | Cladode length | None | - | - | - | - | - |
| | Cladode width | None | - | - | - | - | - |
| *Opuntia exaltata* | Plant height | 9 | 200.00 | 300.00 | 240.8889 | 10.99425 | 32.98274 |
| | Spine size | 9 | 2.00 | 7.10 | 5.7622 | .55441 | 1.66323 |
| | Cladode length | 9 | 12 | 20 | 15.44 | .729 | 2.186 |
| | Cladode width | 9 | 7 | 9 | 7.78 | .278 | .833 |
| *Opuntia ficus-indica* | Plant height | 21 | 110.00 | 300.00 | 227.6190 | 11.17064 | 51.19031 |
| | Spine size | 21 | 1.40 | 7.00 | 3.2595 | .37521 | 1.71942 |
| | Cladode length | 21 | 24 | 67 | 39.91 | 1.977 | 9.059 |
| | Cladode width | 21 | 12 | 29 | 17.69 | .807 | 3.697 |
| *Opuntia monacantha* | Plant height | 8 | 180.00 | 230.00 | 205.8750 | 6.49571 | 18.37263 |
| | Spine size | 8 | 2.20 | 4.60 | 3.9750 | .28142 | .79597 |
| | Cladode length | 8 | 23 | 41 | 33.95 | 2.074 | 5.865 |
| | Cladode width | 8 | 13 | 19 | 15.73 | .762 | 2.156 |
| *Opuntia stricta* | Plant height | 3 | 140.00 | 160.00 | 148.3333 | 6.00925 | 10.40833 |
| | Spine size | 3 | 3.50 | 4.50 | 3.8333 | .33333 | .57735 |
| | Cladode length | 3 | 17 | 22 | 19.33 | 1.453 | 2.517 |
| | Cladode width | 3 | 8 | 10 | 9.00 | .577 | 1.000 |
| *Thrixanthocereus blossfeldiorum* | Plant height | 6 | 250.00 | 285.00 | 271.0000 | 5.35413 | 13.11488 |
| | Spine size | 6 | 2.70 | 3.00 | 2.8500 | .04282 | .10488 |
| | Cladode length | None | - | - | - | - | - |
| | Cladode width | None | - | - | - | - | - |

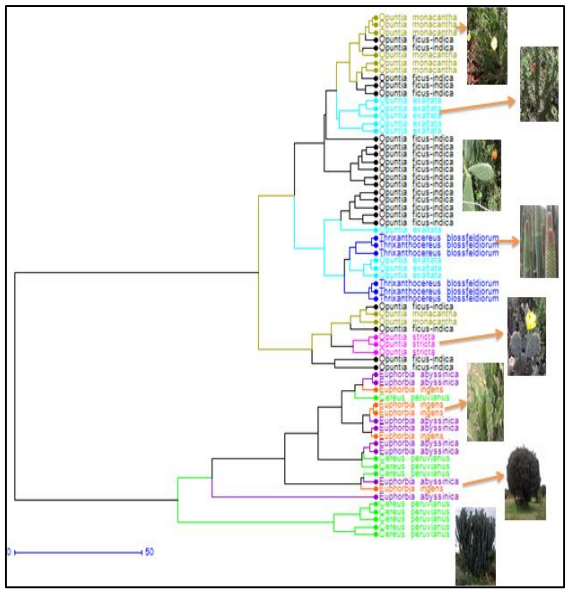

**Fig. 2.** Dendogram showing the diversity of cactus species in Kenya.

## Discussion

This is the first study conducted in Kenya aimed at documenting the status of cactus species in the country. All the species in Kenya may have initially been introduced into the country by white settlers for use as border markers (Kang'ara and Gitari, 2008) in the years between 1940 and 1960 (Kunyanga *et al*., 2009; Githae and Nyangito, 2010).

Eight cactus species were identified in the study areas. These were *Opuntia exaltata, Opuntia monacantha, Opuntia ficus-indica, Opuntia stricta, Thrixanthrocereus blossfeldiorum, Euphorbia abyssinica, Euphorbia ingens* and *Cereus peruvianus* (Table 2). These were distinctly different morphologically by the presence or absence of cladodes which grouped them in two main clusters. All the *Opuntia* species had cladodes while the rest of the genera developed stems and branches without cladodes.

Cladode characteristics were useful in distinguishing species given that cladode size has been suggested to be species dependent (Peña-Valdivia *et al*., 2008a). The accessions cladodes were cylindrical (*Opuntia exaltata*), ovate (*Opuntia stricta,*) or elliptic (*Opuntia monacantha, Opuntia ficus-indica*). Spines were present in all the species with the lower range of 1-2 spines and the highest of 1-7 spines per areole.

Among the Opuntia species (with cladodes), they were distinguished by the shape of the stems in which only *Opuntia exaltata* bore cylindrical cladodes and round stems. *Opuntia monacantha, Opuntia ficus-indica* and *Opuntia stricta* had flat stems. However, *Opuntia ficus-indica* was different from the rest by mostly having thicker elliptic cladodes compared to those of *Opuntia monacantha*. A similar finding was recorded by Chalak *et al*., (2014) in Lebanon.

*Opuntia monacantha* and *Opuntia stricta* bore ovate cladodes. *Opuntia monacantha* produced larger cladode lengths and widths with dark green color compared to the smaller bluish-green to pale-green cladodes of *Opuntia stricta*.

These could further be distinguished by the varying corolla colors. *Opuntia stricta* had bright yellow flowers, an observation similar to that of Majure and Ervin (2007); *Opuntia ficus-indica* had orange flowers while *Opuntia monacantha* had yellow flowers with purple strips. *Opuntia monacantha* and *Opuntia ficus-indica* where generally taller than *Opuntia stricta* which attained heights below two meters. *Opuntia exaltata* produced pink flowers. Only *Thrixanthrocereus blossfeldiorum* in this cluster were columnar with ribbed stems and produced red and ovoid fruits.

*Cereus peruvianus, Euphorbia abyssinica* and *Euphorbia ingens* were relatively tall plants with heights above 4 meters. These were differentiated by the shape of their stem. *Cereus peruvianus* had ribbed stems while the *Euphorbia abyssinica,* and *Euphorbia ingens* bore round stems.

*Cereus peruvianus* was either arborescent or columnar but in some cases the plants were shrubby. In Baringo and Machakos where the plants were grown for ornamental purposes, they took a shrubby form possibly due to management by humans as opposed to Nakuru where they grew naturally without management as either columnar or arborescent. The ripe fruit colors were also distinct where *Cereus peruvianus* produced violet-red and elliptic fruits.

Notably some aged *Opuntia ficus-indica* plants produce cladodes with minimal spines which they later lose as the cladodes age. This may probably be the reason why it could be identified as spineless in some cases. The highest numbers of spines arising from a given areole occurs on the edges of cladodes in most *Opuntia* species this finding is contrary to that of Reyes-Agüero *et al*., (2005) who recorded that the main diagnostic character of *Opuntia ficus-indica* is the partial or total absence of spines.

Further, cladode glochids were observed in 28 of the 41*Opuntia* accessions identified most of which were brown in color. Absence of cladode glochids in *Opuntia exaltata* and some *Opuntia ficus-indica* is an important distinguishing feature from the rest while the two are distinguished by the shape of their cladodes. The existence of majority of cactuses with spines in Kenya's ASALs is by virtue of its effectiveness as fencing and protective barriers. Observations on how cladode characteristics contribute to characterization traits were documented by Peña-Valdivia *et al*., ( 2008).

The corolla color did not directly correspond to the final color of the mature fruit color produced by the same plant. This is because the mature fruit traits were varied. *Opuntia ficus-indica* produced orange fruits; *Opuntia exaltata* had yellowish green fruits while *Opuntia stricta* and *Opuntia monacantha* produced purple fruits. The mature fruit color corresponded to the fruit's pulp color in the identified species except for the *Cereus peruvianus* whose pulp color was white. Thus, the mature fruit color of *Opuntia* species is a direct indicator of the pulp color and the color of juice produced by the species.

High growth and clonal densities of *Opuntia monacantha* observed in Baringo and Laikipia may have been influenced by ease of propagation by vegetative parts (cladodes) spread through human activity and animals including low vegetative covers in these areas. With minimal disruptions by human activities, the densities may spread to cover majority of uncultivated areas since there is a reduced competitiveness of *Opuntia* in places with dense vegetative cover (Erre *et al*., 2009).

There was minimum spread of both *Opuntia stricta* and *Thrixanthrocereus blossfeldiorum* in the areas of study. This could be as a result of their growth characters; *Opuntia stricta* grows less than two meters high while *Thrixanthrocereus blossfeldiorum*'s columnar growth could not be effective as fencing materials as compared to *Opuntia ficus-indica* and *Opuntia monacantha*. Hence, the availability of *Opuntia ficus-indica* and *Opuntia monacantha* in most areas of study may have been influenced by it being effective as fencing material.

The main attributes utilized in this study are agreeable with those utilized by Gallegos-Vasquez *et al*., (2011) who utilized fruits, cladodes and flowers to characterize cactus species.

Although environmental conditions influence the phenotypic characters of cactuses (Peña-Valdivia *et al*., 2008a), there was minimal diversity of the species with respect to the different regions. This suggests reduced environmental influence on the morphological attributes of the species studied. This too could be as a result of similar environmental characteristics of the study areas.

**Conclusion**

The cactus species identified in ASALs of Kenya are diverse and distinct. The following cactus species are present in Kenya; *Opuntia monacantha* in Baringo, Machakos and Makueni counties, *Opuntia exaltata* in Nakuru, Laikipia and Machakos counties, *Opuntia ficus-indica* in Nakuru, Machakos, Baringo and Laikipia counties, *Opuntia stricta* in Makueni County; *Thrixanthrocereus blossfeldiorum* in Machakos; *Cereus peruvianus* in Machakos, Baringo and Nakuru County and the *Euphorbia* spp. in all the five counties studied (Fig. 1).

The common distinguishing features of the available accessions are their growth forms, corolla color, cladodes and fruit characteristics. All these species are exotic and their distribution within the country is predominantly influenced by human activity. There are more spiny types in Kenya since they are selected for making barriers as opposed to vegetable and fodder purposes. More research is needed to cover the entire country to identify other species available in these areas, their mode of distribution as well as productivity.

**Acknowledgements**

The authors are grateful to the Research, Production and Extension Division of Jomo Kenyatta University of Agriculture and Technology for financial support of the study.

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