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DIVERSITY OF ENDEMIC SUCCULENT PLANTS OF NILGIRIS, SOUTHERN WESTERN GHATS, INDIA

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The present study was done for the assessment of endemic succulent plant wealth of Nilgiris. The survey was conducted during 2017 - 2020. The survey in different localities of Nilgiris resulted in identifying a total of 48 succulent flowering plants belonging to 15 families and 27 genera. Among the different families Orchidaceae was leading by 35.4% (17 Spp.) of total endemic plant species followed by Balsaminaceae by 27 % (13 Spp.). Five endangered species explored in the genus are *Impatiens neobarnesii* C. E. C. Fisch., *Impatiens pendula* Heyne *ex* Wight & Arn., *Impatiens nilagirica* C.E.C.Fisch., *Conchidium nanum* (A.Rich.) Brieger and *Gloriosa superba* L. It is concluded that there are no previous reports on the endemic succulent flora in the Southern Western Ghats of Nilgiris, India. Hence, the locality should be further analysed to design conservation measures for the management of these endemic species with environmental quality.

Keywords: Conservation, Endemic, Nilgiris, Southern Western Ghats, Succulent.

Introduction

In the world there are about 17 mega diversity countries where India is one of the mega diversity centres represented by 18,386 species of angiosperms[1]. There are about 4381 endemic species under 1007 genera and 176 families reported in India. Out of these, about 4303 species are angiosperms, 12 species are gymnosperms, 66 species are pteridophytes respectively[2]. Southern Western Ghats and Eastern Himalayas are the two major hotspots for floristic diversity. In a recent compilation[3]. It is observed that Western Ghats harbours the maximum number of endemics represented by 25 – 60% of total endemics in India. The chain of the Western Ghats stretches over an expense of 1600 km north to south, limited in the south by Kanyakumari in Tamil Nadu and in the north by river Tapti in Gujarat. Proportionate levels of endemism increase with the increasing geographical area[4]. Location of endemic centres are Agasthyamala, Anamalai - High Ranges, Nilgiri-Silent Valley, Waynad- Kodagu, Shimoga-Kanara and Palni Hills. Nilgiri district of Western Ghats is the reason for floristic diversity richness in the Tamil Nadu. These endemic areas in India have recorded a maximum diversity of 2611 flora in an area of 2549 sq.km[5]. The centres in and around southern regions of Western Ghats provide unique edaphic, geological and ideal climatic conditions suitable for luxuriant growth of biodiversity. Thus, this region has richer and abundance endemic species[6].

This diversity provides subsistence to the human beings in terms of housing,

medicine and food. However, the prevailing natural biological resources have been continuously depleting due to intense global warming and anthropogenic activities[7,8]. The loss of biodiversity, degradation of habitats destruction modification of natural habitat as well as human activities in the ecosystems are mostly irreversible, ultimately resulting in the extinction of species. The International Union for the Conservation of Nature (IUCN) and the World Wildlife Fund (WWF) estimated that up to 60,000 higher plant species could become extinct or nearly extinct by the year 2050 if the current trends of utilization continues[9,10]. Some hypothesis of the high level of endemism have climatic fluctuations in recent geological time frames, small-scale habitat heterogeneity peculiar substrates and remarkably fast speciation amongst one of the main groups of plants. This area, have been suggested as explanations for the succulent high level of speciation as well as endemism. Also level of endemism may vary in the predictable way along gradients of primary environmental variables such as rainfall, temperature and productivity[11].

The inherent richness and variability in floral diversity, succulent species are one of the defining elements of this region, such diversity makes the predictions of responses to environmental changes like increasing aridity, thermal stress and drought tolerance[12]. Species endemism is one of the criteria for defining biodiversity hotspots for setting conservation priorities. Studies on endemics are useful to understand past vegetational history, identify taxonomic relationships, characterize floristic regions, determine the optimal design of conservation units and prioritize conservation strategies[13]. Most of the localities in Tamil Nadu are underexplored. Therefore, experimental design was carried out to study the endemic succulent plant species survey in physiographic provinces of Nilgiris uphills. The earliest endemic flora study on the Nilgiris was conducted by Blosco, who explored 82 species in 1970. Nayar[14] reported 11 genera in the Nilgiris. Mohanan and Balakrishnan[15] included 818 endemic species belonging to 11 genera in Nilgiris. Nair and Daniel[16] reported 28 species in the Kundah Range of Nilgiris. Ahmedullah and Nayar[17] described *Baeolepis nervosa* (Periplocacceae) exclusive to the Nilgiris. Mohanan and Balakrishnan[15] explored 15 % of threatened orchids in some parts of the Nilgiris region. Narasimhan (2009) has reported 24 taxas as strict endemic to the Nilgiris from Tamil Nadu. Krishnakumar *et al*.[18] had given a detailed account 641 species of flowering plants of sholas and grasslands of the Nilgiris of which 248 species were endemic. Sharmila *et al*.[19] reported 31 endemic species are endemic that are ethnobotanically important plant taxa occuring in the Western Ghats of Nilgiri hills. Ravichandran and Karuppusamy[20] listed 118 endemic flowering plant species from Megamalai Wildlife Sanctuary of the Western Ghats. Prakash *et al*.[21] studied 58 endemic flowering species on Nilgiris, under 43 genera and 27 families particularly from the Gudalur region. Hence the main objectives of the present study is to document and assess the endemic floristic diversity of the Nilgiris through intensive surveys and knowledge about succulents and its state of conservation and management plans before it's lost forever.

Material and methods

Study area:

The Nilgiris district is located in the North Western corner of Tamil Nadu state in South India, between 11° 49' 16" N and 76° 73' 37" E, at the junction of the Eastern and Western Ghats, the two prominent mountain ranges that run almost parallel to the two coastlines of Peninsular India. The Nilgiri hills are a range of mountains with at least

24 peaks above 2400 meters in Southern India where states of Tamil Nadu at the junction of Karnataka and Kerala states. The Nilgiri district also forms the part of the 'Nilgiri Biosphere Reserve' (NBR) which is the first biosphere reserve set up in India under the Indian National Man and Biosphere Programme.

Data collection:

The flowering and fruiting stage of plant specimens were collected from Nilgiris during the month of September 2017 and September 2020. The plant specimens were identified with the help of the local floras[22-24], available floras, revisions and monographs and the conformity of identification was compared with authentic herbarium specimens available at Botanical Survey of India, Southern Circle, Coimbatore. All the flowering parts of the plant collected for studies were subjected to preserve as herbarium specimens based on the standard instructions (Jain and Rao, 2009)[25]. The checklist of endemic plants was confirmed using available pertinent publications[3,25-29]. The voucher specimens were deposited in the Herbarium of the Department of Botany, Bharathiar University, Coimbatore, Tamil Nadu, India. R software was used for graphical representation.

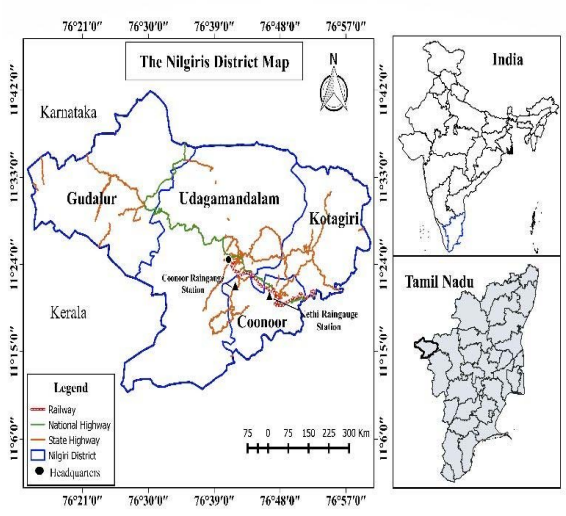

Fig. 1. Study area map

Results and Discussion

The endemism in the flora of a country or geographical region provides an important insight into the biography of that region and also to the centers of diversity and adaptive evolution of the floristic components of that region. It was observed that the study area showed 48 endemic succulent plant species belonging to 15 families and 27 genera (Table-1). Orchidaceae was leading with 17-species (35.4 %) followed by Balsaminaceae with 13- species (27%), Melastomataceae with 3- species (6.25%), Gesneriaceae, Araceae and Commelinaceae with 2-species each (4.16% each) while Lamiaceae, Asparagaceae, Crassulaceae, Apocynaceae, Zingiberaceae, Colchicaceae, Asteraceae, Liliaceae and Apiaceae showed single species each (2.08% each) (Fig. 5.).

The genus *Impatiens* was leading with 13 species (27.08 %), followed by *Habenaria* with 7 species **(**14.58%), *Sonerila* with 3 species (6.25 %), *Arisaema* and *Oberonia* with 2 species each (4.16 % each) while other genus showed only one species (2.08% each**)** respectively. An analysis of the habit of the endemic succulent plant species reveals that amongst the endemics, the herbs dominated more than half of the endemic succulents in Nilgiris with 44 species (91.66%) while climbing habit showed 3 species (6.25 %) such as *Aeschynanthus perrottetii* and *Gloriosa superba* and shrub were single species *Impatiens latifolia* (2.08%**)** (Fig. 6)**.**

The habitat diversity distribution was assessed and the 52 % (25 species) of plant species were lithophytes, 27 % (13 species) were terrestrial, 14.5 % (07 species) were epiphytes, 2.08% (1 species) belonged to lithophyte and terrestrial, 2.08% (1 species) were lithophyte and epiphyte and 2.08% ((1 species) were lithophytes, terrestrial and epiphytic species (Fig. 7.). The study site is known to possess both endangered and critically endangered species such as

Impatiens neobarnesii C. E. C. Fisch., *Impatiens pendula* Heyne *ex* Wight & Arn., *Impatiens nilagirica* C.E.C.Fisch., *Conchidium nanum* (A.Rich.) Brieger and *Gloriosa superba* L.

The parts of the succulents plant diversity was assessed, Leaves and tubers succulents was found to be the most common in the study area with 27 % (each 13 Spp.) followed by 12.5 % (06 Spp.) were leaves succulents, 8.33 % (04 Spp.) were pseudobulbs, 8.33 % (04 Spp.) were petiole, peduncle, leaf, 4.16 % (02 Spp.) were rhizome, 4.16 % (02 Spp.) were petiole, peduncle, tuber and 2.08 % each (01 Spp. each) were peduncle, leaf and stem, petiole and peduncle, bulb were each one species and this was the least common (Fig. 8).

Similar study conducted by Bellard *et al.*[30] showed that a loss of approximately one third of all endemic species within the succulent Karoo (819 species) was due to climate change under emissions scenario. The two major threats suggested to justify their potential impact were land degradation and global climatic change. Biome level approaches underestimate the risk of species diversity loss from climate change impacts in the Succulent Karoo biome because of the large number of narrow range endemics that would likely suffer significant range dislocation with changing conditions[31].

Similarly, Thomas *et al.* [32] suggested that global warming is likely to be the greatest threat in most regions. Their results concluded that migration scenarios were also important in influencing extinctions. The result of Myers *et al*. [33] suggested that the habitat loss in the hot-spots were due to the presence of rapid rates of migration. Several endemic plant species are being documented for their occurrence and distribution in the Western Ghats. The high degree of endemism in the evergreen forests of the Western Ghats can be attributed to the isolation of the Ghats from other moist formations and the prevailing drier climatic conditions in the surrounding areas[34].

Previous work with the endemic survey of Thadagamalai range of the Kanyakumari district, Tamil Nadu has showed that the 25 plant species were found to belong to rare, endangered threatened (RET) categories[35]. A RET climber was identified in Southern, Western Ghats by Sarvalingam and Rajendran[36] have reported 33 species of climber plants from Southern Western Ghats, India. According to Subbaiyan *et al.* [37] about 30 RET species surveyed in the Maruthamalai hills of the Western Ghats categorizing 6 endemic species. Schmiedel *et al*.[38] have published on the vegetative dynamic in the endemic rich quartz field in the succulent Karoo in response to recent climatic trends of South Africa.

Conclusion

Species endemism is one of the criteria for defining biodiversity hotspots for setting conservation priorities. A total of 34 endemic plant species belonging to 13 families and 27 genera were found to be referred for their occurrence in Nilgiri hills. The family diversity showed that Orchidaceae was leading by 48%. The substrate diversity showed that lithophytes were dominant with 65%. A majority of the genus belonged to genus *Impatiens*. The succulent diversity showed that leaf succulent was dominant with 29–%. This data highlights that the knowledge is scarce on the conservation status of the endemic component of the Southern Western Ghats of Nilgiris district. Based on the results, it is concluded that there is a need for an intensive survey of the entire area of Tamil Nadu, the part of Western Ghats to further assess the total endemic plant species for their *in-situ* and *ex- situ* conservation.

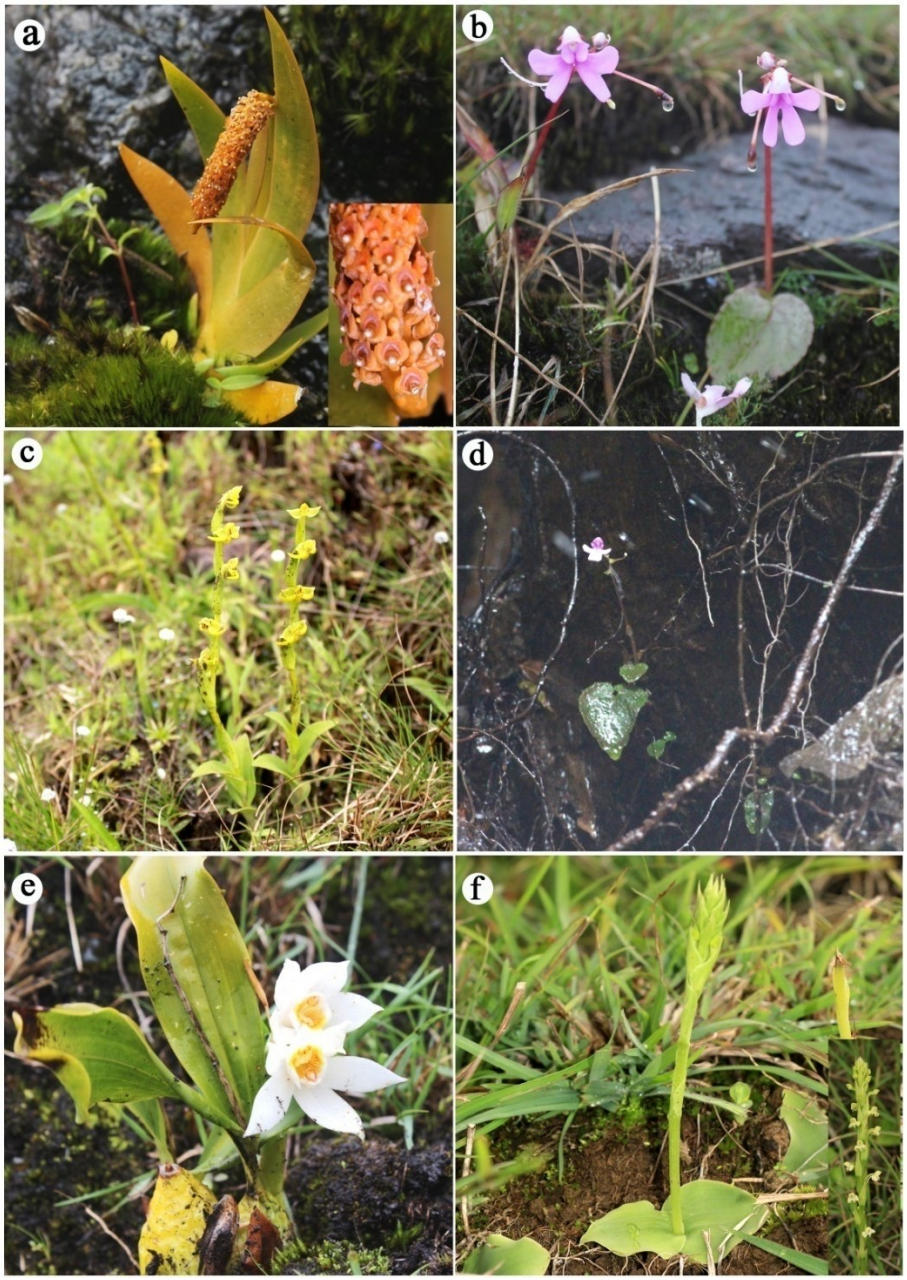

Fig. 2 a. *Oberonia brunoniana* Wight b. *Impatiens pseudo-acaulis* Bhaskar c. *Habenaria barnesii* Summerh. ex C. E. C. Fisch.d. *Impatiens nilagirica* C.E.C.Fisch. e. *Coelogyne nervosa* A. Rich. f. *Habenaria brachyphylla (*Lindl.*)* Aitch.

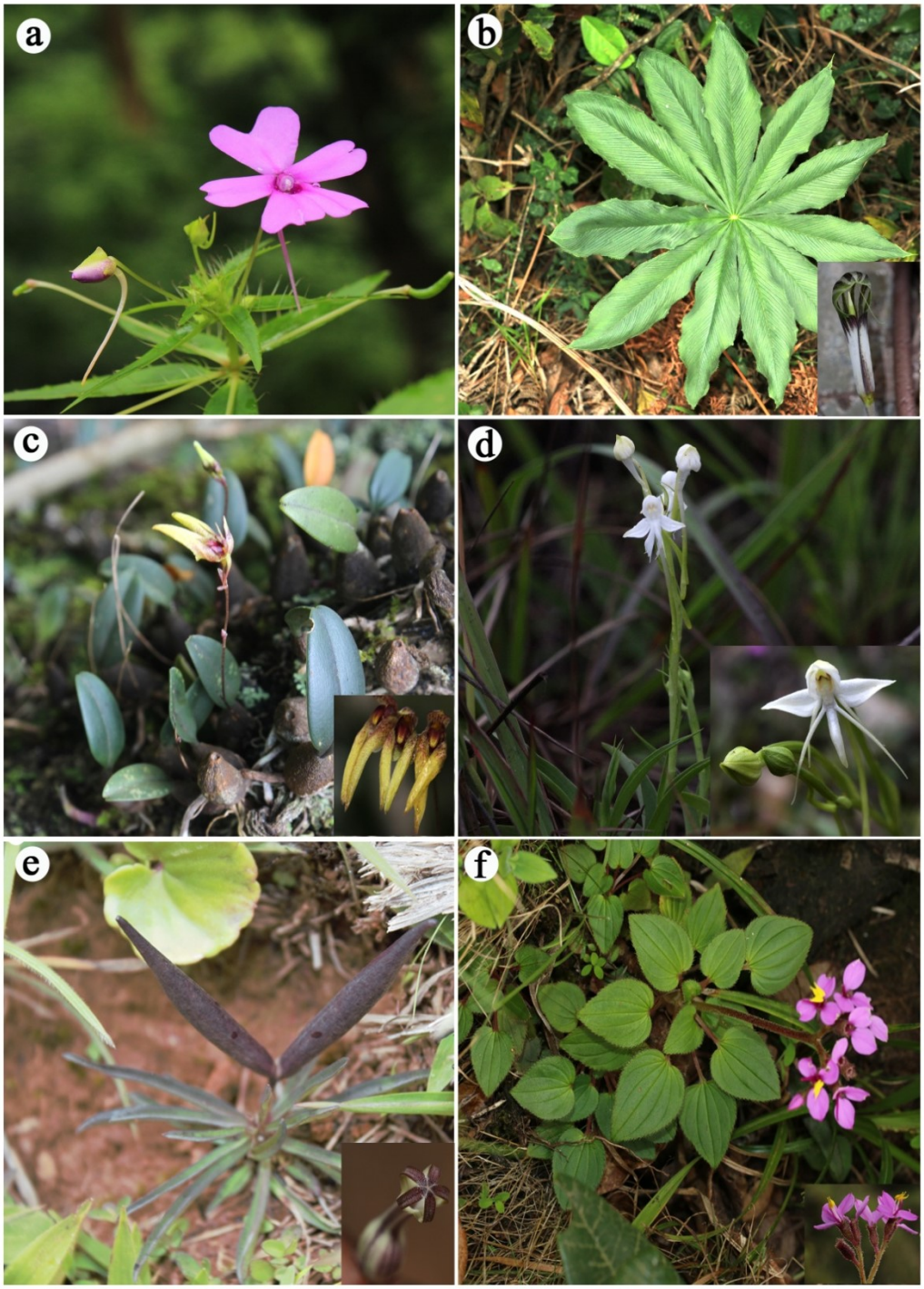

Fig. 3. a. *Impatiens gardneriana* Wight b. *Arisaema translucens* C.E.C.Fisch. c. *Bulbophyllum kaitiense* Rchb.f. d. *Habenaria rariflora* A.Rich e. *Ceropegia pusilla* Wight & Arn. f. *Sonerila speciosa* Zenker

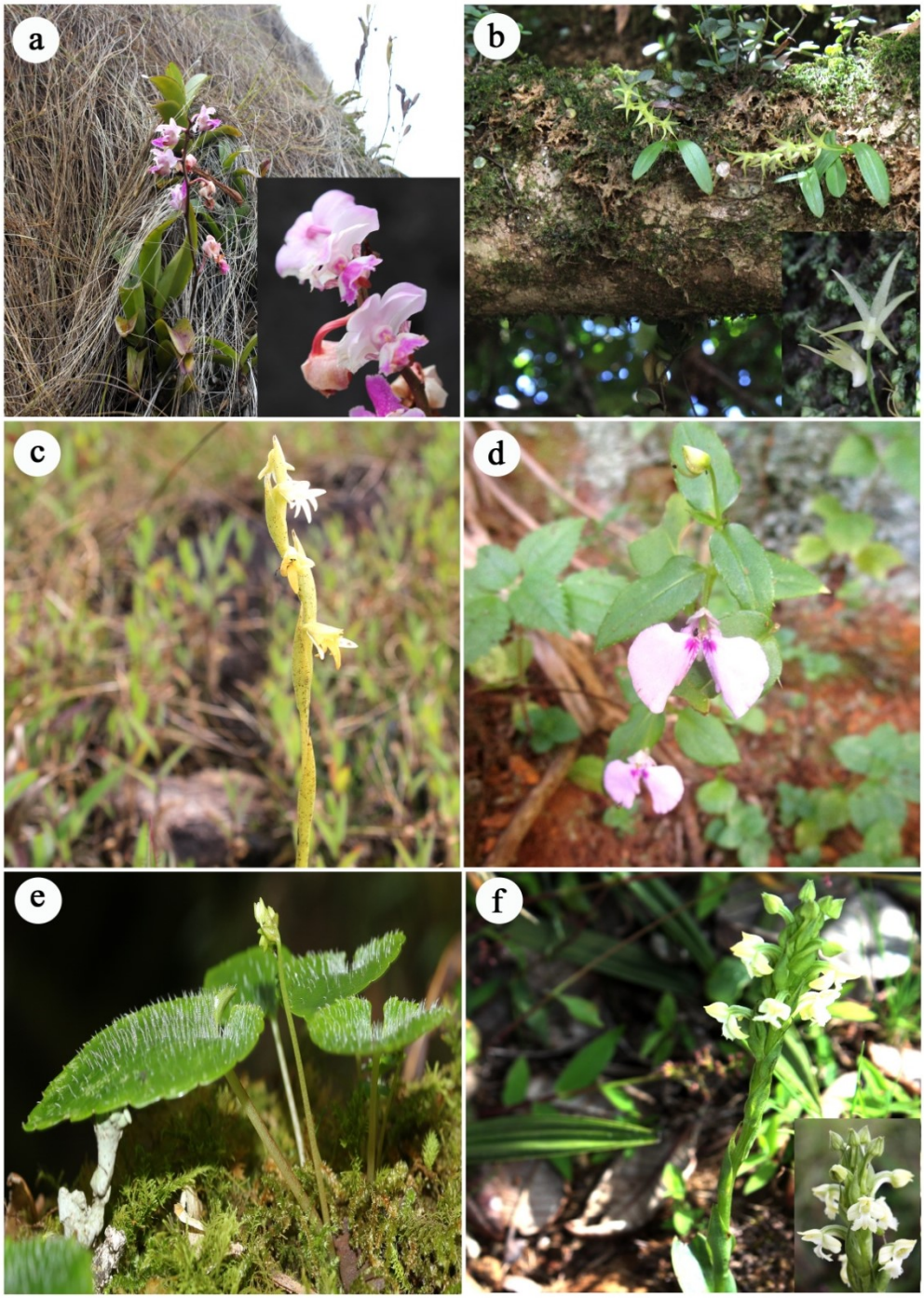

Fig. 4. a. *Aerides crispa* Lindl. b. *Conchidium nanum* (A.Rich.) Brieger c. *Habenaria heyneana* Lindl.d. *Impatiens tenella* Heyne *ex* Hook. f. e. *Impatiens modesta* Wight. f. *Habenaria cephalotes* Lindl.

Table 1. List of endemic succulent species of the Nilgiris, Southern Western Ghats.

S.NO.	Binomial Name	Family	Habit	Habitat	Parts of succulents	Distribution	Endemic status	References
1.	*Aeschynanthus perrottetii* A. DC.	Gesneriaceae	Climber	Epiphtyte	Leaf	Avalanche	Endemic to Western Ghats	Krishnakumar *et al*., 2013
2.	*Aerides crispa* Lindl.	Orchidaceae	Herb	Lithophyte	Leaf	Coonoor	Endemic to Western Ghats	Singh *et al*., 2015
3.	*Anisochilus dysophylloides* Benth.	Lamiaceae	Herb	Lithophyte	Leaf	Pakkasuran hills	Endemic to Nilgiris	Suddee and Paton, 2009.
4.	*Anoectochilus elatus* Lindl.	Orchidaceae	Herb	Terrestrial	Rhizome	Coonoor	Endemic to Southern India	Sameer Patil and Lakshminarasimhan, 2017
5.	*Arisaema leschenaultii* Blume-	Araceae	Herb	Terrestrial /Lithophyte	Petiole Peduncle Tuber	Avalanche	Endemic to Southern Western Ghats	Sharmila *et al*., 2014
6.	*Asparagus fysonii* Macbr.	Asparagaceae	Climber	Terrestrial	Tuber	Avalanche	Endemic to Southern Western Ghats	Singh *et al*., 2015
7.	*Arisaema translucens* C.E.C.Fisch.	Araceae	Herb	Terrestrial	Petiole Peduncle Tuber	Thaishola	Endemic to Tamil Nadu	Singh *et al*., 2015; Prabhukumar *et al*., 2017
8.	*Bulbophyllum kaitiense* Rchb.f.	Orchidaceae	Herb	Lithophyte	Pseudobulb	Thaishola	Endemic to Southern Western Ghats	Singh *et al*., 2015; Nayar and Sastry, 1988; Singh *et al*., 2019; Jeevith *et al*., 2019
9.	*Ceropegia pusilla* Wight & Arn.	Apocynaceae	Herb	Lithophyte	Tuber	Avalanche, Usimalai	Endemic (Karnataka, Kerala, Maharashtra and Tamil Nadu)	Singh *et al*., 2015; Nayar and Sastry, 1988; Singh, 2015
10.	*Coelogyne nervosa* A. Rich.	Orchidaceae	Herb	Lithophyte	Pseudobulb	Coonoor : Usimalai	Endemic to Southern Western	Singh *et al*., 2015; Singh *et al.,* 2019;

							Ghats	Krishnakumar *et al*., 2013
11.	*Curcuma neilgherrensis* Wight	Zingiberaceae	Herb	Lithophyte	Rhizome	Naduvattam	Endemic to Western Ghats	Krishnakumar *et al*., 2013
12.	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Commelinaceae	Herb	Terrestrial	Leaf Stem	Coonoor	Endemic to India	Singh *et al*., 2015; Nandikar and Gurav 2014.
13.	*Conchidium nanum* (A.Rich.) Brieger	Orchidaceae	Herb	Epiphyte	Pseudobul b	Avalanche	Critically Endangered	Singh *et al*., 2015; Singh *et al*., 2019; Jeevith *et al*., 2019
14.	*Dictyospermum ovalifolium* Wight	Commelinaceae	Herb	Terrestrial	Stem	Naduvattam	Endemic to Western Ghats	Krishnakumar *et al., 2013*
15.	*Epithema carnosum* Benth.	Gesneriacaeae	Herb	Terrestrial	Stem	Gudalur	Endemic to Western Ghats	Krishnakumar *et al., 2013*
16.	*Eria pauciflora* Wight	Orchidaceae	Herb	Lithophyte	Pseudobul b	Thaishola	Endemic to Southern Western Ghats	Singh *et al*., 2015; Singh *et al.,* 2019; Krishnakumar *et al*., 2013
17.	*Gloriosa superba* L.	Col chicaceae	Climber	Terrestrial	Tuber	Coonoor	Endangered	Sarvalingam and Rajendran, 2016
18.	*Gynura nitida* DC.	Asteraceae	Herb	Terrestrial	Stem	Ooty: Manjur	Endemic to Western Ghats	Krishnakumar *et al*., 2013
19.	*Habenaria brachyphylla (*Lindl.*)* Aitch.	Orchidaceae	Herb	Terrestrial	Tuber	Coonoor : Usimalai	Endemic to Southern Western Ghats	Singh *et al*., 2015; Singh *et al.,* 2019; Krishnakumar *et al*., 2013
20.	*Habenaria rariflora* A.Rich	Orchidaceae	Herb	Lithophyte	Tuber	Coonoor: Thaishola	Endemic to Western Ghats	Singh *et al*., 2015; Singh *et al.,* 2019; Krishnakumar *et al*., 2013
21.	*Habenaria barnesii* Summerh. ex C. E. C.	Orchidaceae	Herb	Terrestrial	Tuber	Mukurthi National	Endemic to South India	Abraham and Vatsala, 1981; Nayar and

	Fisch.					Park		Sastry, 1988; Singh et al., 2019;
22.	*Habenaria richardiana* Wight	Orchidaceae	Herb	Lithophyte	Tuber	Kotagiri	Endemic Western Ghats	Singh *et al*., 2015; Singh *et al*., 2019; Jalal and Jayanthi, 2012.
23.	*Habenaria longicornu* Lindl.	Orchidaceae	Herb	Lithophyte	Tuber	Kotagiri	Endemic to Peninsular India	Singh *et al*., 2015; Singh *et al.,* 2019; Jeevith *et al*., 2019
24.	*Habenaria heyneana* Lindl.	Orchidaceae	Herb	Lithophyte	Tuber	Mukurthi National Park	Endemic to Western Ghats	Singh *et al*., 2015; Singh *et al*., 2019; Singh Jalal and Jayanthi, 2018.
25.	*Habenaria cephalotes* Lindl.	Orchidaceae	Herb	Lithophyte	Tuber	Mukurthi National Park	Endemic to South India	Singh *et al*., 2015; Singh *et al*., 2019; Krishnakumar *et al*., 2013
26.	*Heracleum sprengelianum* Wight & Arn.	Apiaceae	Herb	Lithophyte	Tuber	Sholur, Usimalai	Endemic to Western Ghats	Krishnakumar *et al*., 2013
27.	*Kalanchoe grandiflora* Wight & Arn.	Crassulaceae	Herb	Lithophyte	Leaf	Sholur	Endemic to Southern Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
28.	*Impatiens latifolia* L.	Balsaminaceae	Shrub	Lithophytes	Stem	Naduvattam	Endemic to Southern Western Ghats	Krishnakumar *et al*., 2013
29.	*Impatiens pendula* Heyne *ex* Wight & Arn.	Balsaminaceae	Herb	Terrestrial/Lithophyte/Epiphyte	Stem	Avalanche, Yellanalli to Ooty road	Critically Endangered	Singh *et al*., 2015
30.	*Impatiens modesta* Wight.	Balsaminaceae	Herb	Epiphyte / Lithophyte	Petiole Peduncle	Upper bhavani and naduvattam	Endemic to Southern Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
31.	*Impatiens levingei*	Balsaminaceae	Herb	Lithophyte	Leaf	Lamb's	Endemic to	Singh *et al*., 2015;

	Gamble *ex* Hook. f.				Petiole Peduncle	Rock Shola forest.	Western Ghats	Krishnakumar *et al*., 2013
32.	*Impatiens clavicornu* Turcz.	Balsaminaceae	Herb	Lithophyte	Leaf Petiole Peduncle	Mukurthi National Park, Avalanche	Endemic to Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
33.	*Impatiens nilagirica* C.E.C.Fisch.	Balsaminaceae	Herb	Lithophyte	Leaf Petiole Peduncle	Avalanche	Endangered	Nayar and Sastry, 1988
34.	*Impatiens minor* (DC.) Bennet	Balsaminaceae	Herb	Terrestrial	Stem	Pandalur	Endemic to Peninsular India	Singh *et al*., 2015; Krishnakumar *et al*., 2013; Jyosna *et al.,* 2011
35.	*Impatiens tenella* Heyne *ex* Hook. f.	Balsaminaceae	Herb	Lithophyte	Stem	Naduvattam	Endemic to Western Ghats of Tamil Nadu and Karnataka	Singh *et al*., 2015; Jyosna *et al.,* 2011
36.	*Impatiens gardneriana* Wight	Balsaminaceae	Herb	Lithophyte	Stem	Pandalur	Endemic to Southern Western Ghats	Krishnakumar *et al*., 2013; Singh *et al*., 2015.
37.	*Impatiens goughii* Wight	Balsaminaceae	Herb	Lithophyte	Stem	Naduvattam	Endemic to Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
38.	*Impatiens neobarnesii* C. E. C. Fisch.	Balsaminaceae	Herb	Epiphyte	Bulb	Mukurthi National Park	Endangered	Nayar and Sastry, 1988
39.	*Impatiens orchioides* Bedd.	Balsaminaceae	Herb	Epiphyte	Tubeous root	Mukurthi National Park	Endemic to Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
40.	*Impatiens pseudo-acaulis* Bhaskar	Balsaminaceae	Herb	Lithophyte	Leaf Petiole Peduncle	Mukurthi National Park	Endemic to South India	Singh *et al*., 2015; Bhaskar, 2012.
41.	*Malaxis intermedia* (A.	Orchidaceae	Herb	Lithophyte	Stem	Lamb's	Endemic to	Singh *et al*., 2015;

	Rich.) Seidenf.					Rock Shola forest.	Southern Western Ghats	Singh *et al.,* 2019; Jeevith *et al*., 2019
42.	*Ophiopogon intermedius* D.Don	Liliaceae	Herb	Terrestrial	Tuber	Thaishola	Endemic to India	Krishnakumar *et al*., 2013
43.	*Oberonia brunoniana* Wight	Orchidaceae	Herb	Epiphyte	Leaf	Gudalur	Endemic to Southern Western Ghats	Singh *et al*., 2015; Singh *et al*., 2019; Krishnakumar *et al*., 2013
44.	*Oberonia verticillata* Wight	Orchidaceae	Herb	Epiphyte	Leaf	Sholur	Endemic to Western Ghats	Singh *et al*., 2015; Singh *et al.,* 2019; Singh Jalal and Jayanthi, 2018. Jalal, 2019
45.	*Seidenfadeniella rosea* (Wight) C.S. Kumar	Orchidaceae		Epiphyte	Stem	Avalanche	Endemic to Southern Western Ghats	Jeevith *et al*., 2019
46.	*Sonerila speciosa* Zenker	Melastomataceae	Herb	Lithophyte	Stem	Sholur	Endemic to Southern Western Ghats	Singh *et al*., 2015; Krishnakumar *et al*., 2013
47.	*Sonerila versicolor* Wight.	Melastomataceae	Herb	Lithophyte	Stem	Naduvattam	Endemic to Southern Western Ghats	Singh *et al*., 2015
48.	*Sonerila rheedei* Wall.	Melastomataceae	Herb	Terrestrial	Peduncle	Gudalur	Endemic to Southern Western Ghats	Singh *et al*., 2015

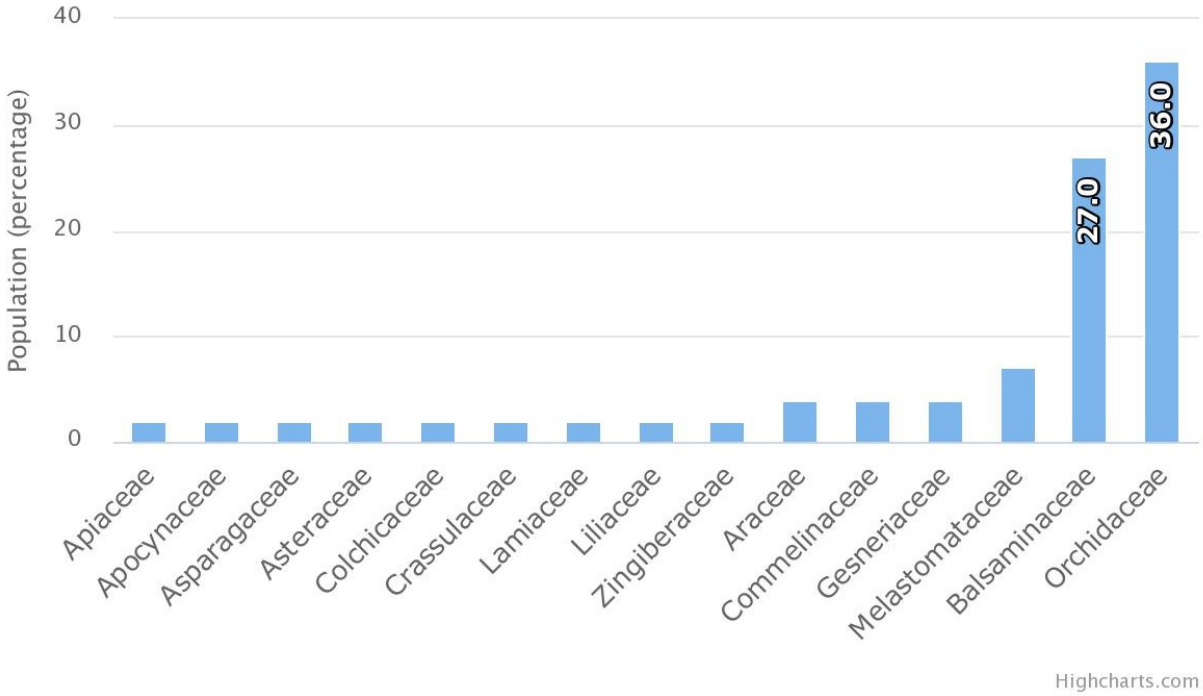

Fig. 5. Distribution of endemic succulent species based on families

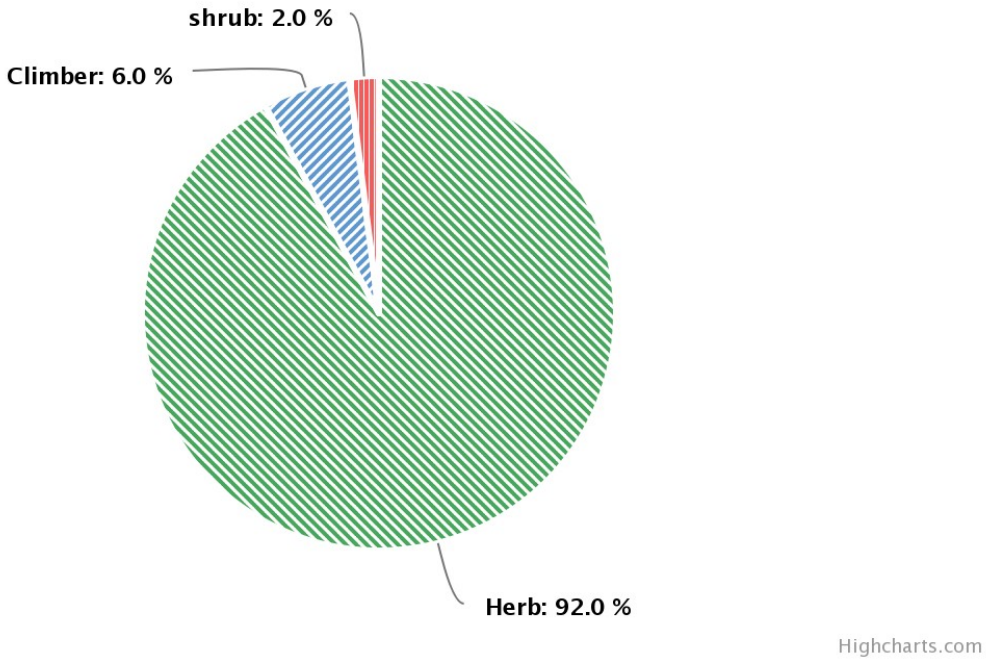

Fig. 6. Distribution of endemic succulent species based on its habit

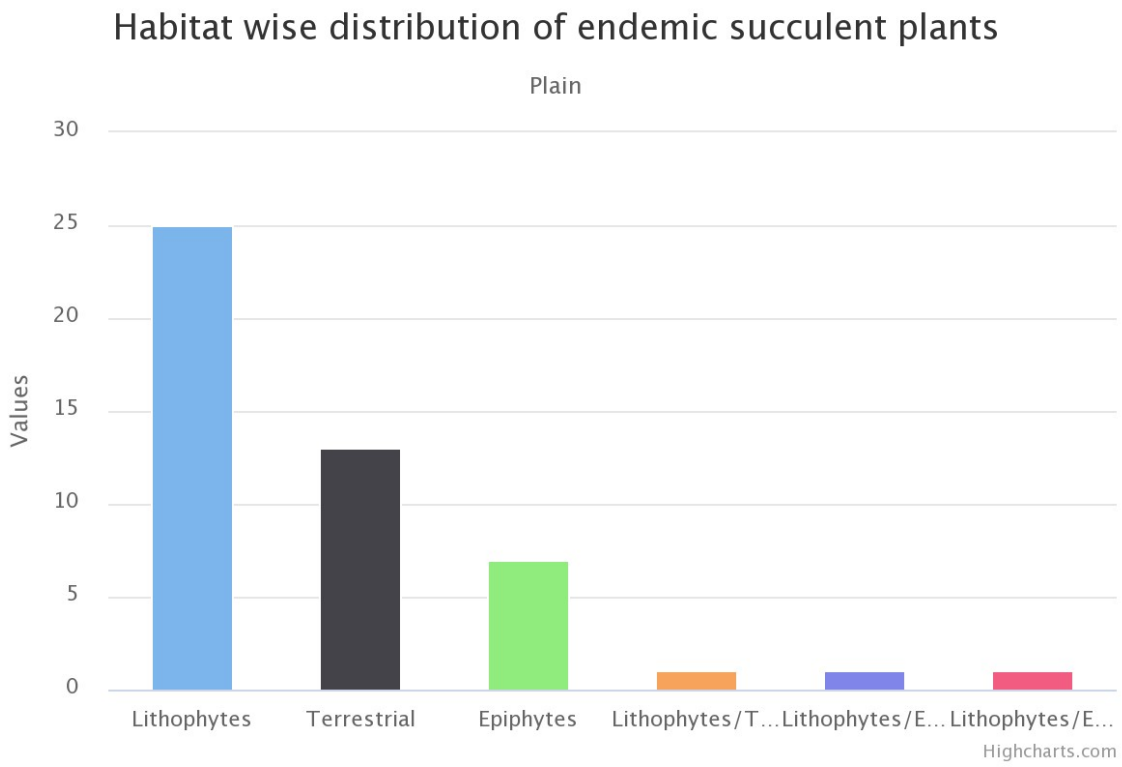

Fig. 7.-Distribution of endemic succulent species based on its habitat

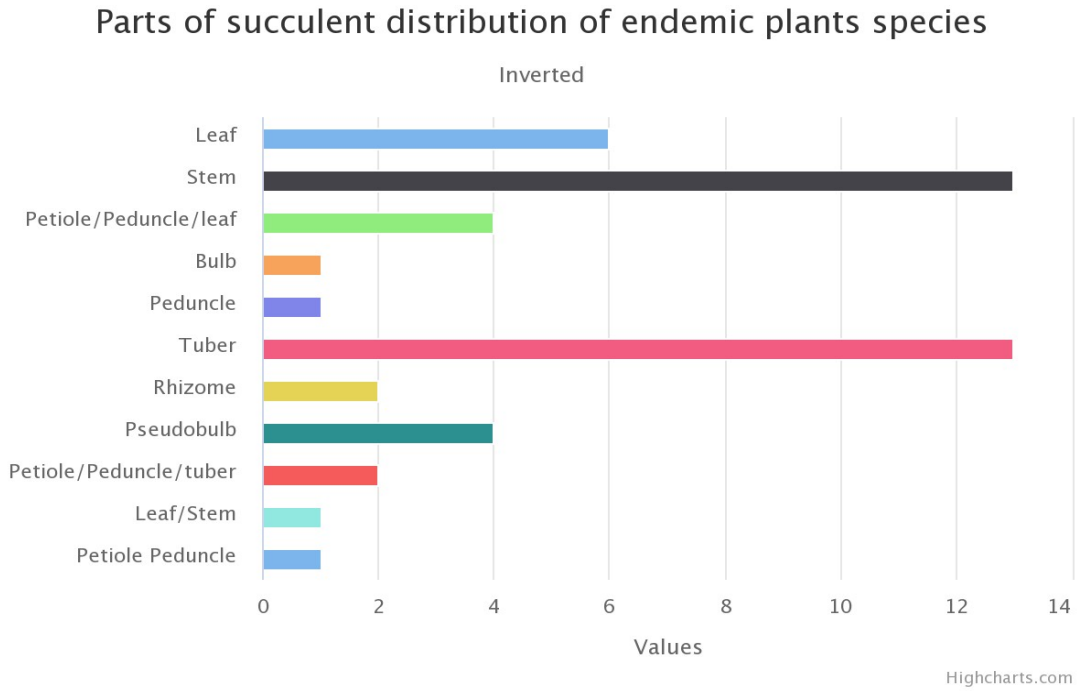

Fig. 8. Analysis parts of succulents distribution in endemic succulent plant species

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