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Review

Check-list and conservation strategies of the genus *Ceropegia* in India

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In India the genus *Ceropegia* is represented by 55 species including four varieties, of which nearly 43 species are facing threats. This genus comprises of medicinal and ornamental species. In this review, we tried to compile the current status of the genus with regard to its distribution, economic importance, propagation methods, conservation through reproduction, micro-propagation and reasons for threat. In the present check-list, the status of the taxa, habit, phenology, Indian and world distribution have been summarized. The importance of the conservational strategies and their success in conserving these valuable taxa is discussed.

Key words: *Ceropegia*, current status, plant tissue culture, reproductive biology, conservation strategies.

INTRODUCTION

The genus *Ceropegia* L. is the largest genus of the tribe Ceropegiaeae with more than 200 species distributed only in tropical and sub tropical regions of the Old World, ranging from the Spanish Canary Islands in the west, through Central, Southern, and Northern Africa, Madagascar, Arabia, India, South Asia to Northern Australia in the East (Good, 1952; Anonymous, 1992; Bruyns, 2003). The maximum diversity of *Ceropegia* occurs in South Africa followed by Kenya and Madagascar. Its species diversity eastwards diminishes in Arabia where only 10 species were recorded and only one species in Pakistan. The species of *Ceropegia* as a whole are under threat, owing to either destructive collection or habitat degradation. They are not only genetically depleted but also are scarcely available. Ansari (1984) revised the Indian *Ceropegia* and reported 44 species, of which 28 are said to be endemic to India. Yadav and Mayur (2008) added 5 novelties to the list. Sachin et al (2006) found the new variety of *Ceropegia oculata* var. *satpudensis* from the Satpuda hill ranges of Maharashtra, India. Nautiyal et al. (2009) rediscovered two endangered or possibly extinct species (*Ceropegia lucida* and *Ceropegia hookeri*) after a gap of 133 years from Sikkim Himalaya. Another new species *Ceropegia bhatii* was discovered by Yadav and Shendaga (2010) from Karnataka, India. In our check list, the number of species increased to 55 taxa including four varieties (Table 1), of which 38 species occur in Western Ghats (Yadav and Mayur, 2008). Many species of the genus *Ceropegia* have now been added to the list of Indian endangered plants (BSI, 2002). These species are placed under the categories of rare, endangered, vulnerable, extinct, and threatened plants (Nayar and Sastry, 1987; Goyal and Bhadauria, 2006; Madhav Gadgil, 2004). In China there are 17 species with two species overlapping with India (Li et al., 1995). In India there seems to be two major distributions of this genus, the Himalayan region and peninsular region. The Himalayan species do not possess tubers and are non-succulent and herbaceous (Bruyns, 1997).

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Table 1. Check-list of Indian *Ceropegias*.

S/N	Species	Status	Habit	Flowering/Fruiting	Distribution	
					India	World
1	*Ceropegia anantii* Yadav et al.	Endemic	Herb	July-Oct.	Sindhudurg (Maharashtra state)	India
2	*Ceropegia andamanica* Shreekumar et al.	Endemic	Herb	Dec.	Andaman and Nicobar Islands	India
3	*Ceropegia angustifolia* Wight	Rare, endemic and threatened	Herbaceous twiners	July-Sept.	Meghalaya, Sikkim, Arunachal Pradesh, West Bengal, Uttar Pradesh	Bangladesh, India, Nepal
4	*Ceroepgia anjanerica* Malpure et al.	Endemic	Perennial erect herb	July-Sept.	Nasik (Maharashtra state)	India
5	*Ceropegia arnottiana* Wight	Rare, endemic	Tuberous twiners	Sept.	Goa, Karnataka, Meghalaya	India
6	*Ceropegia attenuata* Hook.f.	Endangered, endemic	Tall tuberous herbs	Aug.-Oct.	Karnataka, Goa, Maharashtra (Raigadh, Pune), Rajasthan	India
7	*Ceropegia barnesii* Bruce & Chatterjee	Endangered, endemic	Twiners with glabrous stem	May-June	Karnataka (South Canara), Tamil Nadu (Nilgiri hills)	India
8	*Ceropegia beddomei* Hook.f.	Endangered, endemic	Hairy twiner	Nov.	Kerala (Trivandrum, Oinmudi; Idukki), Peermade	India
9	*Ceropegia bhatii* Yadav & Shendage	Critically endangered, endemic	Twiners	Aug.-Nov.	Davanagere Karnataka	India
10	*Ceropegia bulbosa* Roxb. var. *lushi* Hook.f.	Common	Tuberous twiners	July-Oct.	Throughout the India.	India, Pakistan
11	*Ceropegia bulbosa var. bulbosa Roxb.*	Common	Tuberous twiners	July-Sept.	Punjab, West, Peninsula, Uttar Pradesh, throughout India.	Yemen, India, Pakistan, Ethiopia, Somalia
12	*Ceropegia candelabrum L. var. biflora (L.) Ansari*	Rare	Glabrous twiners	Aug.-Dec.	Andhra pradesh, Karnataka, Kerala, Orissa, Tamilnadu	India, Pakistan

Table 1. Contd.

13	*Ceropegia candelabrum L. var. candelabrum*	Rare	Tuberous twiners	Aug.-Nov.	Andhra pradesh, Assam, Gujarat, Karnataka, Kerala, Madhya Pradesh, Orissa, Tamilnadu	India, Srilanka
14	*Ceropegia ciliata* Wight	Endemic	Tuberous twiners	Aug.-Sep.	Tamil Nadu, Kerala	India
15	*Ceropegia decaisneana* Wight	Ornamental	Climbing herbs	Oct.-Dec.	Kerala, Tamil Nadu, Karnataka	India, Sri Lanka
16	*Ceropegia elegans* Wall.var. *elegans*	Occasional	Glabrous twiners with fascicled roots	June-Dec.	Karnataka, Kerala, Tamil Nadu	India, Sri Lanka
17	*Ceropegia ensifolia* Bedd.	Endemic	Twiners with subglobose tubers	Aug.-Sept.	Kerala, Tamil Nadu	India
18	*Ceropegia evansii* Mc Cann	Endemic	Twining herb	July-Sept.	Maharashtra (Khandala, Pune)	India
19	*Ceropegia fantastica* Sedgwick	Threatend, endangered	Twining herb	July-Oct.	Goa, Daman & Diu Karnataka (Sulgeri, North Karnataka)	India
20	*Ceropegia fimbriifera* Bedd.	Endangered	Twining herb	July-Aug.	Karnataka, Kerala (Travancore hills) Tamil Nadu	India
21	*Ceropegia hirsuta Wight & Arn.*	Endemic	Coarse tuberous twiners	July-Nov.	Throughout India except Himalayan region	India, Thailand
22	*Ceropegia hookeri C.B. Clarke ex Hook.f.*	Endangered	Twining herb	June-July	Sikkim	India, Nepal
23	*Ceropegia huberi Ansari*	Endemic, endangered	Twiners with subglobose tuber	Aug.-Sep.	Maharashtra (Varadha Ghat; Kolhapur, Satara, Susake island; Ambar ghats)	India
24	*Ceropegia intermedia Wight var. wightii*	Endemic	Glabrous twiners	Aug.-Jan.	Tamil Nadu, Kerala, Karnataka	India
25	*Ceropegia jainii Ansari & Kulk*	Endemic	Erect, dwarf, tubersous herb.	Aug.-Sep.	Sahyadri range- Maharashtra	India
26	*Ceropegia juncea Roxb.*	Occasional	Succulent climbing tuberous herb	July-Nov.	Andhra Pradesh, Sikkim, Maharasthra, Kerala, Kakrnataka, Tamil Nadu	India, Sri Lanka

Table 1. Contd.

27	*Ceropegia kochinensis* Prain	Threatend	Twiners	Oct.-Nov.	Sikkim, Bangladesh and Burma	India, Myanmar
28	*Ceropegia hookeri* Clarke ex. Hook.f. var. *hookeri*	Threatened	Twiners with tuberous rhizomes	Dec.-Feb.	Sikkim	China, Bhutan, India, Nepal, Tibet
29	*Ceropegia lawii* Hook.	Endangered, endemic	Tall erect tubers herbs	Aug.-Oct.	Maharashtra (Konkan Harishchandragad)	India
30	*Ceropegia longifolia* Wall.	Occasional	Twiners with fascicled roots	Aug.-Sep.	Himachal Pradesh, Meghalaya, Mizoram, Sikkim, Uttar Pradesh, West Bengal, Arunachal Pradesh	India, Nepal, China, Bangladesh, Burma
31	*Ceropegia longifolia* Wall. var. *sinensis* Huber	Rare	Twiners	July-Aug.	Meghalaya, Assam, Sikkim	India, China, Bangladesh
32	*Ceropegia lucida Wall.*	Endangered	Twiners	June-Aug.	Meghalaya, Uttar Pradesh, West Bengal	India, Bangladesh, Burma, China, Hongkong, Malaysia, Thailand
33	*Ceropegia maccannii Ansari*	Rare / endangered, endemic	Tall erect tubrous herb	July-Oct.	Maharashtra	India
34	*Ceropegia macrantha Wight*	Occasional	Twiners	June-Aug.	Skikim, Meghalaya, Himachal Pradesh, Uttar Pradesh, West Bengal, Madhya Pradesh, Kashmir,	India, Nepal, Bhutan, Pakistan
35	*Ceropegia maculata Bedd.*	Endangered / extinct (?)	Glabrous twiners with fibrous roots	June-Feb.	Kerala, Tamil Nadu,	India, Sri Lanka
36	*Ceropegia mahabalei Hem. & Ans.*	Endangered, endemic	Tall, erect tuberous herb	Aug.-Oct.	Pune, Thane Maharashtra	India
37	*Ceropegia media (Huber) M.Y.Ansari*	Endemic	Slender tuberous herbs	Aug.-Oct.	Maharashtra – Pune, Satara, Ratnagiri	India
38	*Ceropegia metziana Miq.*	Rare, Endemic	Twiners	Sept.-Dec.	Karnataka, Kerala, Tamil Nadu	India

Table 1. Contd.

39	*Ceropegia mohanramii* Yadav	Endemic	Tuberous erect herb	July-Nov.	Sindhudurg (Maharashtra state)	India
40	*Ceropegia noorjahaniae* Ansari	Rare, endemic	Erect tuberous herbs	July-Oct.	Maharashtra (Panchgani Ghats, Satara district)	India
41	*Ceropegia oculata* Hook. var. *oculata*	Rare, endemic	Slender tuberous herbs	July-Oct.	Maharashtra (Pune; Ratnagiri, Raigad), Kerala, Tamilnadu	India
42	*Ceropegia oculata var. satpudensis*	Endangered	Twinig herb	Aug.-Nov.	Maharashtra (Satpura hill ranges)	India
43	*Ceropegia odorata Nimmo ex Hook.f.*	Endemic	Slender tubrous twiners	Aug.-Sept.	Gujarat (Pavagadh) Maharashtra (Melghat) Rajasthan (Mt Abu)	India
44	*Ceropegia omissa Huber*	Endemic	Glabrous twiners	Sept.	Tamil Nadu (Sengalteri, Tirunelvely)	India
45	*Ceropegia panchganiensis Blatter & Mc Cann*	Endangred, endemic	Tall erect tuberous herbs	July-Aug.	Satara, Ahmednagar-Maharashtra (Panchgani, Lingamala)	India
46	*Ceropegia pubescens Wall.*	Endangered	Twiners	June-Sept.	Meghalaya, Nagaland, Sikkim, West Bengal	India, Nepal, Bhutan, Tibet, China
47	*Ceropegia pusilla Wight & Arn.*	Endemic	Dwarf, erect, tuberous herbs	June-Aug.	Karnataka (Mysore), Kerala, Maharashtra, Punjab, Tamil Nadu	India
48	*Ceropegia rollae Hemadri*	Rare, endemic	Tall erect, tuberous herb	Aug.-Sept.	Maharashtra - Pune	India
49	*Ceropegia sahyadrica Ans. & Kulk.*	Endemic	Erect, tuberous herb	Aug.-Sept.	Maharashtra (Pune & Sindhudurg district)	India
50	*Ceropegia santapaui Wadh. & Ans.*	Rare, endemic	Tuberous twiners	Aug.-Sept.	Maharashtra (Pune; Satara; Ratnagiri)	India
51	*Ceropegia schumanniana Swarup. & Mangaly*	Endemic		Dec-Aug.	Tamil Nadu	India
52	*Ceropegia spirilis Wight*	Vulnerable, endemic	Erect tuberous herb	Aug.-Oct.	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu	India

Table 1. Contd.

53	*Ceropegia thwaitesii* Hook.	Vulnerable, endangered	Glabrous, twiners	April-June	Tamil nadu, Kerala	India, Sri Lanka
54	*Ceropegia vincifolia* Hook.	Endemic, endangered	Tuberous twing herb	Aug.-Sept.	Maharastra – (Raigad, Satara, Sindhudurg)	India
55	*Ceropegia wallichi* Wight	Rare, endemic	Tall, robust erect herbs	May-June	Himachal Pradesh, Uttar Pradesh	India, Nepal

The various species of the genus were placed into 21 sections by Huber (1957) in his revision of the genus and the Indian species fall under 10 sections of this revision. Some species show various forms of succulence in stem, leaf and tuber and they are mostly found in Africa and Madagascar (Meve, 2002). The hall mark features of *Ceropegia* are its tuberous roots and elaborate flowers. The corolla is tubular and dilated at the base. The corolla lobes are generally united at the tips. The leaves may be linear or broad and some species are erect and some are climbing in habit.

In India, there are three widespread species *Ceropegia bulbosa*, *Ceropegia juncea* and *Ceropegia hirsuta*. Many species of the Northern Western Ghats are endemic to the region (Malpure et al., 2006). Twenty species occur in the western Indian state of Maharashtra of which 14 spp. occurs only in Maharashtra. Most of the endemic species of Western Ghats are restricted to a narrow range of distribution and some of them occur only in their type localities. Species like *C. evansii, C. fantastica, C. huberi, C. lawii, C. maccannii, C. mahabalei, C. noorjahaniae, C. odorata, C. panchaganiensis, C. rollae, C. sahyadrica,* and *C. santapaui* may become extinct in few decades unless conservation measures are taken.

Nautiyal et al. (2009) pointed that there is urgent need to understand the genetic architecture and evolutionary relationship of *Ceropegia* spp. to ensure their reestablishment in nature and to grow in botanical, herbal gardens and in other protective areas. Surveswaran et al. (2009) worked on the molecular phylogeny of *Ceropegia* (Asclepiadoideae, Apocynaceae) of Indian Western Ghats. In their study, they concluded that the *Ceropegia* includes taxa of diverse geographical origins and apparently a long history of independent evolution, allowing for the accumulation of nucleotide substitutions and insertions/ deletions in their non-coding nuclear and plastid DNA regions. The fast rate of evolution at the molecular level is in sharp contrast to the seemingly conservative morphological features, such as their characteristics pit fall flowers. On the other hand, convergent evolution in morphological features can lead to leaping divergent species into the same taxonomic group. This later scenario seems to be a more likely explanation for the discrepancy between morphological classification and molecular phylogeny of *Ceropegia* and *Brachystelma*.

Sumangala et al. (2009) developed fourteen microsatellite markers for *C. fantastica*. The microsatellites developed for this species could be used for addressing population genetics of this endemic and critically endangered species. A total of 14 primers were designed for the sequencing results and of these only eight successfully amplified at the expected size. The microsatellite markers thus obtained were cross amplified in two related species namely; *C. hirsuta, C. oculata.* All the primers cross amplified with both the population genetic structure of other closely related species of *Ceropegia*.

DIVERSITY AND CONSERVATION OF CEROPEGIA - A REVIEW ON PRESENT STATUS

Economic importance of the genus *Ceropegia*

The sweet-sour leaves are edible and are considered to be tonic and digestive. The tubers are edible (Mabberly, 1987) and contain starch, sugars, gum, albuminoids, carbohydrates, fats, crude fibre, and the medicinally important alkaloid cerpegin (Kirtikar and Basu, 1935; Nadkarni, 1976; Anonymous, 1980; Jain and Defillips, 1991). The boiled or roosted tubers are edible and a rich source of carbohydrates (Nikam and Savanth, 2007).

These species are of economic importance (Jagtap and Singh, 1999) due to their starchy edible tubers with medicinal value. The fresh tubers of these species are usually boiled before they are eaten to remove the bitterness. The active compound of tuberous roots is the alkaloid cerpegin which is active against diarrhea and dysentery inflammation of gums and delirious fevers of parturition (Nadkarni, 1976). The alkaloid cerpegin from the tubers of *C. bulbosa* was used in Bihar to cure cold, sneezing and eye diseases (Kirtikar and Basu, 1935). The Indian species of this genus possess ornamental attributes that can be preserved through domestication which will allow us to introduce a new flower in the bouquet.

Reasons for threatened status

Several species within this genus are rare and endangered. The major threats to these plants are habitat destruction and local peoples' use of the edible tubers as food. Due to the elaborate flower forms and ornamentation, several species have horticultural value (CITES, 2007). In most of the Indian *Ceropegia* species, the starchy tubers are prone to fungal infections and thus decay of tubers is a major problem in their cultivation and maintenance. They dislike organic manure and excess watering. Over exploitation of *Ceropegia* species for these tubers by humans and various animals, endemism, small and localized populations, and severe anthropogenic pressures on the forest land have caused their decline in the wild; influence of human activities is intense especially in the northern zone of Western Ghats which has been subjected to rapid urbanization in the recent past because of its proximity to the international and economic hub city Mumbai.

PROPAGATION METHODS

Through reproduction or *in vitro* propagation

Natural obligation for cross pollination coupled with low seed production is unsuitable for propagation through seeds. Though the tuber is perennial, in one growth season it produces only a single plant. The natural populations are rapidly decreasing due to consumption of tubers by humans and animals. Vegetative propagation by root tubers is tedious, and is too low to meet the commercial needs (Beena and Martin, 2003). Therefore, there is an urgent need for conservation measures like *in vitro* propagation of these species.

Pollination and reproductive biology

Ceropegia flowers are usually found in shady hidden places and are well adapted for fly pollination. Patil et al. (2005) observed flowering in some *Ceropegia* species like (*C. attenuata, C. bulbosa, C. bulbosa* var. *lushii, C. hirsuta, C. lawii, C. mahabalei, C. media, C. oculata* var. *subhirsuta, C. panchaganiensis, C. rolle,* and *C. vincaefolia*) while cultivating *in vivo,* of which fruit production had been reported only in few species like *C. attenuata, C. bulbosa, C. bulbosa* var. *lushii, C. hirsuta, C. lawii, C. mahabalei,* and *C. rollae*.

Pollinators

Among the Asclepiadoideae the tribe *Ceropegiaeae* to which *Ceropegia* belongs is the most specialized in terms of pollinating insect species since it is solely pollinated by dipterans (Ollerton and Liede, 1997). Delpino (1869) documented the first observations on the fly trapping mechanisms of *Ceropegia* flowers during pollination, these observations were corroborated by Kunth (1909) in his synthesis of knowledge on pollination biology at the time of using the Asian *C. elegans* as an example, he noted that small, two-winged flies carry pollinaria on their proboscis. Pollination in the species of *Ceropegia juncea* Wight in Southern India is studied based on observation from *ex situ* grown plants and confirmed pollinators are small, mostly female dipterans flies, ca. 3 mm long, which carry pollinaria on the proboscis (Karuppusamy and Pullaiah, 2009). The most important factors for an insect to effect pollination appear to be the appropriate overall size, mouth parts and adjacent pads on which a pollinarium can attach. Pollination in the genus *Ceropegia* (Apocynaceae /Asclepiadaceae) in east Africa is discussed based on field observations and herbarium studies. All inferred or confirmed pollinators are small, mostly dipterans, measuring about 2.5 mm long. The most important factor for an insect to effect pollination appears to be the appropriate overall size.

Self pollination

Spontaneous germination of pollinia still attached to the stylar head has been incidentally observed in some specimens in cultivation, e.g. *Ceropegia stenoloba* var. *moyalensis* (Masinde, 2004). This phenomenon raises the question as to weather self-pollination is possible in some *Ceropegia* species.

Barad (1990) observed the growth of pollen tubes while pollinia were still attached to the gynostegium in some stapeliads, thus implying the possibility of self-pollination. It has been demonstrated by artificial pollination experiments that self-pollination is possible in some stapeliad species (Bosma, 1994). We also observed single follicle development due to self-pollination while micropropagating the endangered *Ceropegia spiralis* (Figure 1). However, it has also been noted that cross-pollination is usually more successful (Barad, 1990; Bosma, 1994). Chaturvedi (1988) records natural self-pollination in another asclepiad, *Tylophora hirsuta*,

Figure 1. *Ceropegia spiralis* showing single follicle.

caused by spontaneous germination of the pollinia still attached to the stylar head. No pollination experiments have ever been successfully attempted in *Ceropegia*, due to the complex floral morphology.

Plant tissue culture studies

Natural propagation of these plants is not at a pace to overcome the exploitation and destruction in the wild. Propagation from seeds is held back by low germination and survival rates due to the inept environmental conditions. As a result their wild populations are diminishing at an alarming rate. Such conditions have also thinned the possibilities of an *in situ* conservation of these plants. Propagation of *C. candelabrum* through seeds is held back by a low span of viability and a low germination rate of seeds and scanty and delayed rooting of seedlings. Seed-derived progenies are not true-to-type due to cross-pollination. Vegetative propagation by root tubers is onerous, and too low to meet the commercial needs (Beena and Martin, 2003). Vegetative propagation methods through stem cuttings that are well established for many of the American and European *Ceropegia* species (Mc New, 2002; Hodgkiss, 2004; Reynolds, 2006), but cannot be employed for the Indian species, asthey do not respond to such practices, probably because of their specialized adaptations to respective microclimatic conditions. Consequently, conservation measures supported by *in vitro* methods are required (Patil, 1998; Walter and Gillett, 1998; Beena et al., 2003). These plants have responded promisingly to the *in vitro* experiments, signifying the utility of such technology (Patil, 1998; Beena et al., 2003; Britto et al., 2003; Nair et al., 2007). However, diligent approach to meet the propagation requirements for reintroduction of these plants is still awaited (Table 2).

Because of their solitary nature *in vivo* tubers do not ensure the multiplication of plants, *in vitro* micro-tuberization would be an ideal strategy for these plants if microtubers can be yielded throughout the year and would be advantageous over the seasonal seeds (Fay, 1992). Microtubers are easy to acclimatize and reintroduce in comparison with the other propagules. They are easy to store and are less vulnerable to transportation conditions; they also get established fast in soil and thus are the choice of interest for international germplasm transfer (Malaurie et al., 1998). Micropropagation through tissue culture may help in the multiplication and reestablishment of these species back into the wild (Britto et al., 2003; Murthy et al., 2010a, b). Britto et al. (2003) cultured *Ceropegia bulbosa* var. *bulbosa* and reported the induction of *in vitro* flowering, tuberization and shoot multiplication from nodal explants.

Beena et al. (2003) mainly focused on the rapid *in vitro* propagation of the medicinally important *Ceropegia candelabrum.* Starting from a single node explant, 250 rooted shoots were obtained within a period of 120 days. This protocol is efficient to propagate this medicinal plant en masse to keep pace with the commercial needs and also to prevent the species from going into extinction. Beena and Martin (2003) established an efficient *in vitro* propagation method for *C. candelabrum* through somatic embryogenesis. The protocol described in this study facilitates development of 2500 *C. candelabrum* plantlets per one gram of callus via somatic embryogenesis within 6 months. This culture method will be useful for conservation and to the improvement of *C. candelabrum* using gene transfer technologies.

Goyal and Bhadauria (2006) micropropagated *C. bulbosa,* a scarcely available plant. The purpose of this study was to develop *in vitro* techniques through nodal explants for conserving the species. Nair et al. (2007) suggested that the protocol developed by them is applicable across the wide range of *Ceropegia* species. Moreover, induction of flowering in all six species of *Ceropegia* in the experiment indicated marginally superior

Table 2. Tissue culture studies in *Ceropegia*.

S/N	Species name	Source of explant	Result	References
1	*Ceropegia attenuata* Hook.f.	Seeds / nodes	Micropropagation and *in vitro* flowering	Chavan et al., 2011
2	*Ceropegia barnesii* Bruce & Chatterjee	Different explants	Micropropagation, conservation	Ananthan, 2003
3	*Ceropegia bulbosa* Roxb.	Node	Multiple shoot induction, plantlet propagation	Patil, 1998
		Stem segments	Callus culture, plantlet propagation	Patil, 1998
		Seeds	Polyembryony	Raghuramulu et al., 1999
		Node, Root, cotyledon, leaf, stem segments	Multiple shoot induction, plantlet propagation, Callus culture, plantlet propagation	Raghuramulu and Pullaiah, 1999
		Seeds	Twin seedlings	Raghuramulu et al., 1999
		Nodes	Micropropagation	Rathore et al., 2010
4	*Ceropegia bulbosa* var. *bulbosa* Roxb.	Node	Multiple shoot formation, *in vitro* flowering, microtubers	Britto et al., 2003
		Seeds	*In vitro* flowering	Nair et al., 2007
		Nodal segments	*In vitro* propagation	Goyal and Bhadauria, 2006
5	*Ceropegia bulbosa* var. *lushii* Hook.f.	Stem segments	Callus culture, plant regeneration	Patil, 1998
		Node	Multiple shoot induction, plantlet propagation	Patil, 1998
6	*Ceropegia candelabrum* L.	Node	Axillary bud multiplication, rooted *in vitro*	Beena et al., 2003
		Leaf, internode segments	Callus induction, somatic embryo-genesis, plantlets from embryoids	Beena and Martin, 2003
7	*Ceropegia fantastica* Sedgw	Nodal segments, seedlings and shoots	Seed germination. Shoot induction, multiplication	Chandore et al., 2010
8	*Ceropegia hirsuta* Wight & Arn.	Seeds	Microtuber production and proliferation	Pandit et al., 2008
		Seeds	*In vitro* flowering	Nair et al., 2007
		Nodal segements	Micropropgation	Nikam et al., 2008
9	Ceropegia intermedia Wight	Axillary shoots	Conservation and micropropagation	Karuppusamy et al., 2009
10	Ceropegia jainii Ansari & Kulk	Node	Multiple shoot induction, plantlet propagation	Patil, 1998
		Stem segments	Callus culture, somatic embryogenesis	Patil, 1998
11	Ceropegia juncea Roxb.	Nodes	Multiple shoots, callus culture, Ceropegin estimation.	Nikam and Savanth, 2009
		Aseptic seedlings	Multiple shoots	Krisnhareddy et al., 2011

Table 2. Contd.

12	*Ceropegia lawii* Hook.	Seeds	*In vitro* flowering	Nair et al., 2007
		Seeds	Microtuber production and proliferation	Pandit et al., 2008
13	*Ceropegia maccannii* Ans.	Seeds	*In vitro* flowering	Nair et al., 2007
		Seeds	Microtuber production and proliferation	Pandit et al., 2008
14	*Ceropegia noorjahani* Ansari	Axillary bud	Multiple shoot formation, rooted *in vitro*	Kedage et al., 2006
15	*Ceropegia oculata* Hook.	Seeds	*In vitro* flowering	Nair et al., 2007
		Seeds	Microtuber production and proliferation	Pandit et al., 2008
16	*Ceropegia pusilla* Wight & Arn.	Different explants	Propagation, conservation	Ananthan, 2003
		Node, TCLS, Internodes	Morphogenetic callus and multiple shoots	Kondamudi et al., 2010
		Node, Internodes	Micropropagation and *in vitro* flowering	Kondamudi and Murthy, 2011.
17	*Ceropegia sahyadrica* Ans. et Kulk.	Seeds	Microtuber production and proliferation	Pandit et al., 2008
		Seeds	Callus culture and micropropagation	Nikam and Savant, 2007
		Seeds	*In vitro* flowering	Nair et al., 2007
18	*Ceropegia spiralis Wight*	Nodes, TCLS internodes	Micropropagation, Multiple shoot induction	Murthy et al., 2010
		Callus	Somatic embryogenesis	Murthy et al., 2010
		Node, Callus	*In vitro* flowering	Murthy and Kondamudi, 2010
		--	Micropropagation	Chavan et al., 2011
		TCLs	Rapid shoot regeneration	Murthy and Kondamudi 2011

effect of sucrose to that of 6-Benzylaminopurine (BAP). Though these species belong to different microniches, they still respond to similar culture conditions, suggesting that the protocol can be comprehensively used across the range of *Ceropegia* species. Nikam and Savanth (2007) focused on the callus cultures, micropropagation and domestication of *C. sahyadrica*. They had some proposals to improve this plant via genetic engineering in the field concerned with tubers just like potatoes etc. Pandit et al. (2008) gave a comprehensive protocol for the microtuberization for threatened *Ceropegia* species. They proposed a novel phenomenon of microtuber proliferation. However, for effective reintroduction of these plants, these *in vitro* efforts must be backed by the habitat conservation and other appropriate *ex vitro* strategies.

Nikam et al. (2008) established a protocol for *in vitro* micropropagation of *C. hirsuta* through optimization of cytokinins and auxins and then transfer of plants to the field condition. The shoot regeneration was direct from nodal explants, which has been crucial for employing micro-propagation techniques for plant regeneration and conservation as it ensures genetic stability. Karuppusamy et al. (2009) developed a protocol for micropropagation of *C. intermedia*, an endemic plant of south India. They concluded that the outline of the protocol offers a potential system for improvement, conservation and micropropagation of *C. intermedia* from nodal explants.

Nikam and Savanth (2009) optimized a protocol for the *in vitro* propagation and callus culture of *C. juncea*, it offers the possibilities of using organ/callus culture techniques for vegetative pro-pagation and production of the alkaloid cerpegin and studies on biochemical and secondary metabolites. Murthy et al. (2010a, b) developed a reproducible protocol for the propagation of the endangered species *C. spiralis*; the aim here is to produce plants in shorter period and to test the scope to domesticate the species as it has beautiful flowers and medicinal properties as well. In order to produce with utmost speed, they followed thin cell layers (TCLs) method and somatic embryogenesis. Kondamudi et al. (2010) in their study induced an excellent development of a callus which had the ability for organogenesis and morphogenesis for the endangered taxon *C. pusilla*. Chandore et al. (2010) developed a novel *in vitro* protocol for multiplication and restoration of *C. fantastica* in Western Ghats. Chavan et al. (2011) reported an efficient protocol for *in vitro* propagation of *Ceropegia spiralis*, an endemic and rare potential ornamental plant of Peninsular India. Chavan et al. (2011) evaluated factors effecting *in vitro* propagation of *C. attenuata* and reported high frequency of shoot induction was achieved on Murashige and Skoog (MS) medium containing higher concentrations of 6-Benzylaminopurine (BAP). Krishnareddy et al. (2011) reported an efficient protocol for multiple shoot induction in *C. juncea.*

Conclusions

Here we are mainly stressing upon the conserva-tion of this valuable genus and establishment of alkaloid cerpegin production from callus cultures. Application of these protocols is of economic use for the industrial production and consequently, conservation of the tuberous *Ceropegia* species. However, for effective reintroduction of these plants, these *in vitro* efforts must be backed by the habitat conservation and other appropriate *ex vitro* strategies.

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