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Climate change on orchid population and conservation strategies: A review

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Orchidaceous are the most diverse group of plants with estimate of more than 25000 species (Dressler, 1993). Distribution and abundance of orchids vary between continents and within regions, following hotspot of species richness (Myers *et al.*, 2000). Epiphytic orchids are available plenty in the Andes of S. America, Madagascar, Sumatra and Borneo; Indo-China for both epiphytic and terrestrial species, and South-Western Australia for terrestrial orchids (Cribb *et al*., 2003).

Orchid is suffering from an uncertain future through over exploitation, habitat loss due to human activities and impact of climate change. The Earth climate system constantly adjusts between the received energy from the sun and the energy goes from the Earth to space. The misbalance of energy causes the warming of the Planet. The global warming is changing the timing of important developmental and behavioral events. Warming of climate affects the species ranges and interaction with existing tropic range. Global warming forces plants to migrate to higher latitudes and altitudes in search of new suitable habitat (Chen *et al*., 2011). Some species experiences loss of habitat, population reduction and risk of extinction which can not keep pace with the climate change (Root *et al.*, 2003; Thomas *et al.*, 2004). The phenological changes occurred due to global climate change alter the population levels and have profound impact on ecosystem and evolution. Climate change interacts with habitat loss and fragmentation; newly introduced ones along with existing species and population growth will bring the modification of many ecosystems. The climate change will be a threat to the conservatory or biosphere for existing or endangered orchid species.

The future of orchid population is disturbing and the world will face the extinction of many species. In Asia, climate change occurs rapidly due to compound pressure on natural resources and the environment associated with rapid urbanization, industrialization and economic development. In Latin America, significant loss will be visible in species. In Eastern Australia there will be an increased risk of drought and fire which imbalance the diversity of flora and fauna. Global warming will bring unpredicted rainfall in the world and will cause drought to devastating flood, land sliding and many more loses (Solomon *et al.*, 2009).

Factors affecting rarity of orchids

Survivality of orchid is correlated with the abiotic and biotic factors and their interactions for growth, development and reproduction.

Abiotic Factors

Anthropogenic threatenening is directly reducing the distribution and abundance of a species such as collecting of wild orchids or land clearance (Cribb *et al.,* 2003; Koopwitz *et al.,* 2003). It is not only accelerating the environmental conditions and habitat change adversely necessary for sustaining orchid population, but also jeopardized total system of existence. Abiotic factors impose significant and dreaded threats to orchid conservation particularly in the face of climate change (Dixon *et al.*, 2003). Orchid and ecosystem have become vulnerable to extinction because of excessive anthropogenic pressure particularly imposed by the human activities. Fragmentation of habitats, indiscriminate collection, habitat destruction, increased susceptible to fire threat, pollinator decline will result in the drastic loss in orchid population and diversity (Sosa and Platas, 1998; Hopper, 2000; Coats and Dixon, 2007). The increased global temperature is invariably co-related with the abiotic factors which determine the orchids population in a region.

Biotic factors

Activity of biotic factor on abundance and distribution of orchids arises as a result of natural factors. In the case of terrestrial orchids, distribution and abundance may be governed by factors related to underground and above ground life history phases of species (Clements, 1988; Dixon, 1989). The underground phase requires a mycorrhizal association with a fungal endophyte (Ramsay *et al.,* 1986; Rasmussen, 2002) symbiotic relationship between orchid and mycorrhizal fungi; is considered to be vital in natural seed germination, seedling growth and post seedling growth of all orchid species (Dearnaley, 2007; Rasmussen and Rasmussen, 2009). The environmental factor influences the function and stability of orchid mycorrhiza (Batty *et al.,* 2001b). However, it is not clear how and whether the function of mycorrhiza fungi in orchid germination and growth will be maintained with arising temperature, erratic rainfall

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and reduced moisture. The above ground phase is effective to pollination of orchids.

In vast system of plant kingdom, orchids adopted to attract pollinators ranging from vertebrates to invertebrates (Tremblay *et al.,* 2005). Similar to mycorrhizal association, pollination systems may play a vital role in rarity of orchids. The pollination of orchids is for food or deception system, strongly influences it's mating system and out crossing capability. High proportion of deceit is a trend towards reduction in the number of pollinator species per orchid species combined with habitat requirements (Roberts, 2003). Environmental change affects the long term survivability and evolutionary potential of specialized potential of pollination (Roberts, 2003). Changes in breeding systems involved self pollination are more likely to occur in species at ecological frontiers. Increase in temperature with increased in CO_2 levels although results in vegetative growth of the plant, flowering period would be adversely affected. Early or late flowering of any particular orchid species would indirectly affect its pollination.

Orchid population and global climate change

The cycles of climate change driven by natural factors occurred over a period of centuries. Climate change forces the species to migrate pole ward in an orderly manner (Darwin, 1859). The response of species or population in relation to climate change depends on the species biology and the geographic location of the population. In general populations in the flat terrain moved toward upward or pole ward during warming period (Jackson *et al.,* 1987). While those in mountainous area with mild slopes, migrated upward along the elevation gradient (Thomson, 1990). However, in regions with complex habitat, steep and uneven slopes, rare species shrinking in population sizes and face local extinction (Maschinski *et al.,* 2006).

There is evidence that vegetational zoning on tropical mountains is strongly controlled by temperature (Primack and Corlett, 2005). Further it is predicted that increasing temperature may results in vegetational zones gradually moving vertically towards mountain side and as a consequence low land species to migrate upwards and gradual elimination of species of upland (Foster, 2001). Apart from this, the warming of temperature will bring difference in cloudiness which will hamper the orchid population. Orchid populations on or close to the tops of mountains may be similarly vulnerable to climate warming. Penetration of light and heat in a forest depends on the thickness of vegetation. Many orchids in upper forest canopies are sensitive to desiccation due to heat (Benzing, 2004). Orchids and other epiphytes share nutrition, light, temperature and moisture in the complex web of the plant canopy. Global warming is affecting the availability of light, nutrition and moisture. Being the nature of hardiness, orchid can tolerate slight variations of temperature and light, but reports indicate that climate variations over a decade has forced orchids to migrate to better places.

During last 30 years or more number of European terrestrial orchids have continued to decline due to climate change, habitat loss and fragmentation. However it is reported that *Himantoglossum hircinium* has begun increasing again like *Ophrys splegodes* in England, may be due to climatic interference (Kull and Hutchings, 2006). Orchids are peculiar for specific habitat requirements, deficiency of any of the requirements leads to their rarity (Cribb *et al.,* 2003). Erratic rainfall or evaporation rate will misbalance the soil moisture, vegetation and microclimate of forest area or grassland (Bates *et al.,* 2008). It will likely impact on terrestrial orchids population. Extreme rainfall can accelerate erosion. Increased degree and frequency in erosion may negatively affect the plant population of orchids in hills. Species of *Calanthe, Eria, Paphiopedilum, Pholidota* and *Obeneria* are more vulnerable under this situation. The climate change caused the drought which threatened the long-term survivality of orchids like *Melaleuca* (Swarts and Dixon, 2009a).

The majority of orchids have specialized pollination system (Tremblay *et al.,* 2005). Some species of orchid may be pollinated by some specific species of pollinator (Shi *et al*., 2008; 2009). The long time flowering behaviors are rare for orchids (Wills *et al.,* 2008). Fluctuations in flowering time due to fluctuations in spring temperatures have been documented for number of woody species and herbaceous species. Phenology of some subtropical species can be temperature driven. Increase of temperature during winter and spring may hasten the flowering of orchids. As majority of orchids pollinators are insects, the unusual flowering will fail to invite insect pollinators for pollinations which in term decrease orchid population. The higher temperature coupled with low precipitation will cause more forest fire (Primack and Corlett, 2005) killing all flora and fauna associated with ecological niche. The frequent forest fire will lead to extinction of local species. Further, the severe frost in winter followed by extreme dry spell in spring caused drying of epiphytic orchids in the host plant.

Potential solutions

A number of strategies can be taken to conserve the orchids due to threat imposed by climate change.

(a) Restoring and maintaining native ecosystem

In conservation, restoration may be defined as the manipulation of organisms and ecological processes to create self organizing, sustainable, native ecosystems as integral parts of the landscape, as much as possible as they existed before disruptive human disturbances. Re-creation of previous habitat or ecosystem in which orchids used to grow is very difficult due to increasing human population, fragmentation of forest, over collection of exotic species, extinction of native species; competition for soil, water and light; and land conversion for human activities. Restoration of richness species in a new prototype ecosystem is little easier than the rare type of species because their basic biology was not studied properly, less multiplication rate and loss of habitat. Loss of genetic diversity and lack of local ecotypes are also a limitation to restoration.

Before restoration of orchids in a habitat, the priority is to create natural forest with the local flora as much as possible as the local flora are more adapted to local conditions.. However, afforestation with align species the establishment may not be fruitful. Restoration and maintaining native ecosystem in the era of global warming is challenge to the environmentalists. Keeping in view of global warming, Murthy *et al.* (2010) suggested some mitigation measures: modifying the forest working plan preparation process, incorporating the projected climate change and likely impacts; initiating research on adaptation practices, covering both conservation and forest regeneration practices; linking protected areas and forest fragments; anticipatory planting of species along the altitudinal and latitudinal gradient; adopting mixed species forestry in all afforestation programmes; incorporating fire protection and management practices, and implementing advance fire warning systems.

Orchids are generally epiphytes, terrestrials, lithophytes or saprophytes based on their growing habits and specific to particular climatic requirement. Thus, safeguarding orchids in changing climatic conditions would be an extensive follow up process that would promote maintenance and restoration of native orchids. The existing ecosystem can be enhanced or rebuilt by afforestation and reforestation, inclusion of new species and strict measures to prevent loss of gene pool. Assisted colonization similar to reintroduction can be an option to species conservation of orchids because the target species will move to an environment suitable for them in future (Seddon, 2010; Liu *et al.*2012).

(b) Managing habitat for rare, threatened and endangered species

Although orchids belong to largest family with more than 25000 species, many of these are threatened, endangered or extinct usually due to habitat destruction or climate change. A number of species like *Anoectochilus sikkimensis, Anoectochilus rotundifolius, Arachnis clerkei, Bulbophyllum albidum, Bulbophyllum rothschildianum, Bulbophyllum yunnanensis, Calanthe alpinia, Calanthe mossiae, Calanthe nitida, Cymbidium whiteae, Dendrobium pauciflorum, Dendrobium tenuicaule, Didiciea cunninghamii, Eulophia nicoberica, Habenaria richardiana, Liparis pulchella, Paphiopedilum druryi, Paphiopedilum fairrieanum, Paphiopedilum hirsutissimum, Paphiopedilum wardii, Phaius mishmensis, Pleione lagenaria, Renanthera imschootiana and Zeuxine pulchra* of India are rare, extinct, endangered and threatened.

A great many of the rare plants can be conserved by keeping their native habitats healthy. A periodic monitoring needs to ensure that rare plant populations are still thriving. Periodic monitoring of healthy rare plant populations can protect their long term existence. In some cases, conserving and protecting the existing habitat of rare species, such as forest or vegetation can save the plants. Sometimes rare or threatened species require specific microclimate or soil for their existence which is very difficult to recreate once the environment. Good quality habitat and maintenance of ecological process for these rare orchids are the best hope for conservation of orchids. In some rare orchids, pollinators are essential for seed production. In these cases multiplication outside, replanting in the habitable area and monitoring of pollinators can be a solution for conservation. Therefore, strict vigilance is required from the government agencies, NGOs, village communities etc. for protection of the existing rare orchids.

(c) Ranking vulnerability of species

Orchids became rare, endangered, extinct, threatened due to human interference and moreover by climate change. Indicator like habit, flowering time, population size, distribution patterns as well as geographical range can be effective tools for prioritize species based on vulnerability of wild species in relation to global warming. Ranking system will help to select and identify species. Restoration actively can be done on priority basis for more vulnerable species.

(d) Long term phenological monitoring for plants and pollinators

The current global warming has a great impact on phenology of plants and pollinators. Changes in species range and tropic relationships in relation to climate warming affect their interactions. Phenological changes population levels and community dynamics was already established that fluctuation in temperature influenced the flowering of woody plants and herbaceous plants in temperate zones (Fitter and Fitter 2002; Menzel *et al.,* 2006; Dose and Menzel, 2006). Matching of orchid flowering and visits of insects (pollinator) is important as most of the orchids are cross pollinated.

Orchid pollination systems evolved mainly in response to competition for pollinators (Benzing and Atwood,1984) in a condition where pollinators are not frequent for pollination (Darwin,1885). There are so many species which offer no floral reward but depends on the food deceptive mechanism to attract pollinators (Montalva and Ackerman, 1987; Calvo, 1990; Christensen, 1992). Nectar is the common reward for pollination (Dresslar, 1981). Inflorescence size also contributes to attract pollinators (Willson and Price, 1977; Ackerman, 1989). Flowering periods are frequently associated with the period of emergence of insect foragers and optimum reproductive success is linked with the period during which inexperienced pollinating insects can be deceived (Nilsson, 1992). This temporal association is especially important for early flowering species pollinated by newly emerged foraging bees, such as *Orchis mascula*. The *Orchidaceae* is the only plant family in which pollination by sexual deceit is known (Dafni, 1984; Nilsson, 1992; Schiestl, 2005; Tremblay *et al.,* 2005).

Therefore, supervision on flowering behavior of orchids and visit of pollinators needs to be monitored regularly for long term. Even then the mismatches in phonological responses to temperature fluctuations between orchids and their pollinators will be helpful for assess the population decline.

(e) Assisted migration for orchids conservation

Assisted migration is the intentional establishment of population beyond the boundary of a species historic range for the proposed of tracking suitable habitats through a period of changing climate. This might involve migration between islands, up mountain slopes and between mountains top (Keel, 2005). Assisted migration does not replace other strategies like restoration, reintroduction and introduction as a tool of conservation. Assisted migration may also include new conservation areas which will become very important as habitats shift in response to climate change. The assisted migration of any plant to a site beyond present change will constitute the introduction of an unwanted species. Assisted migration must be applied on a case by case based on scientific experiment, with monitoring for several years and assessment stress to mitigate unforeseen problem. The assisted migration plan should include important threat, mode of predicted outcome and management plan (Fox, 2007; Mc Lachlan *et al.,* 2007). Assisted migration can be applied in such a way as to minimize the problem of invasive species regardless of public policy. Selection of species, site of introduction and risk factors like landscape fragmentation, rarity of species, habitat, altitudes or longitudes, population sizes etc. are equally important for assisted migration. Further, while implementing assisted migration for orchid conservation climate condition like light, temperature and humidity requirements; physical and chemical condition of soil; plant competition; life and demographic history; pollination behaviour *etc* should be considered (Keel, 2005).Such efforts require integration among the reintroduction sides. Adopting the general rules of temperature gradient along altitudinal or coordinate gradients (Cowell *et al.,* 2008; Jump *et al.,* 2009), a 500m upward migration is sufficient for track a species in near future.

(f) Symbiotic seed germination and seedling growth for restoration of orchid

Symbiotic seed germination of orchids is well documented and presented by many workers (Bernard, 1909; Hadley, 1970; Ramsay *et al.*, 1986; Zetler *et al*., 2003; Batty *et al.,* 2006). Mycorrhizal associations of orchids are important in implementing recovery and restoration programme. Mycorrhizal relationship needs to study thoroughly for individual orchid species in conservation sites. Besides mycorrhizal association, the climatic factors like temperature and moisture relationship with orchids should be investigated thoroughly along with other variables in determining population dynamics of orchids. Seed and seedlings inoculated with appropriate fungi will overcome the hindrance from lack of adequate symbiotic fungi. The use of molecular approaches to identify fungal associates has dominated the research of orchid fungal relationships. Analysis of DNA sequences permits rapid interference of taxonomic affinities of orchid's endophytes. An understanding of mycorrhizal diversity associated with species targeted for reintroduction is crucial for success of rehabilitation efforts (Swats and Dixon, 2009b). Rehabilitation or restoration of targeted orchids in a new area depends on the thorough understanding of fungal association to prioritize conservation.

(g) Intra- species hybridization

There are so many species which have greater adoptability that overlapping the different zones *i.e.* a tropical orchid may be available in subtropical warmer or subtropical cold zones. The hybridization of orchid of warmer zones to cold zones

Damage due to deforestation and urbanisation

Damage due to landslides

Indeterminate type of orchid

Endangered type of orchid.

Rare type of orchid

Extinct type of orchid

will improve the heat tolerance. Hybridization systems are most important factors determining variability in plant species (Hamrick, 1989; Harrision, 1993). Orchids are self- compatible and autogamy barriers occur before pollination (Dressler, 1993; Borba and Semir, 1999). Self- incompatibility are found in some species and usually associated with cross pollination. Hybridization of orchids species are mechanical and related species are potentially inter fertile (Dressler,1993; Borba and Semir,1999). The role of hybridization of orchids in invasion and adaption to climate changes is a key area which will provide simulation research. The micro evolutionary potential of the species needs to study thoroughly before conducting such programme.

(h) Seed storage and banking

A number of causes are there for depletion of species of orchids. The critical factors are undoubtedly decrease of fungi required for seedling development, change of microclimate associated with orchid growing. Seed storage and banking of orchid seed is a good option for checking the loss of orchid habitat in the alarming situation of climate change. The seed to seed banking conditions of orchid vary from retaining high viability at subzero temperatures to use of -70°C conditions for *Dactylorhiza, Dendrobium, Eulophia* and *Paphiopedilum* species (Pritchard *et al*.,1999). The total loss of viability was found in the *Cattleya aurantiaca* (Seaton and Hailes 1989) or partial loss of viability in a two out of three co-occurring native Australian terrestrial orchids (Batty *et al.,* 2001a).

Storage at subzero temperature for long periods can lead to an increase in germination ability in some orchids species (Batty *et al.*,2001a) and it might be associated with the lipid body dissociation during the freeze and thawing cycle (Pritchard,1984). An in depth research to establish appropriate seed moisture and temperature conditions is required to ensure longevity of stored seed prior to embarking on an orchid seed storage programme. It was reported that dry seeds of some species of orchid can be stored for at least 20 years at refrigerated temperatures. Although some orchid seeds are short lived, majority of orchid species are capable of tolerating dry storage, probably for many decades when stored at -20 C (Seaton and Pritchard, 2003). Large number of seed can easily be stored for their small size (0.05 to 6 mm) and weight (0.31- 24 micrograms) in a small container which will be suitable for banking of seed. A domestic freezer can be used for storing of seed. Cryopreservation of seeds can be a viable option for storing seeds for longer periods.

The aim of seed banking is to exchange the materials within the research institute or the countries rich in orchid biodiversity.

Indian scenario

India is considered as one of the mega Biodiversity of orchids in the world with two major biodiversity hot spots: the Eastern Himalayas and the Western Ghats. These zones cover tropical, sub tropical and temperate climate with lush green and divers forests in which multitudinal biotypes co-existed. Mishra (2007) estimated 1331taxa under 185 genera of orchids in India. The distribution pattern reveals five major phyto-geogaraphical regions viz., North Eastern Himalaya, Peninsular region, Western Himalaya, Western Ghats and Andaman Nicobar group of islands. The share of each state of India in orchid diversity as well as regions is enumerated in Table 1 and Table 2. Approximately 60 percent of the species of Indian origin are epiphytic, while the rests are terrestrials, lithophytes or saprophytes. However, certain genera like *Cymbidium* and *Liparis* have both epiphytic as well as terrestrial species. Among the 800 epiphytic species, mostly are distributed in North Eastern Himalaya followed by 300 species in Western Ghats, 200 species in North West Himalaya.

Both the Eastern Himalaya and Western Ghats contribute majority species in India. In India the contributions are as follows: North Eastern Himalaya -900, Eastern Himalayas -730, Eastern India-130, Peninsular India -267, Central and Gangetic plains -60 and Andaman and Nicobar Islands -117 species. Nearly 300 species in 75 genera are endemic (Rao, 1991). There are some species which can be found in different climatic zones *i.e*. same species are available in tropical as well as in subtropical zone. It is due to greater adaptability of orchids. Orchid diversity in India is seriously threatened by biotic influences, socio economic pressure and indiscriminate collection, destruction of forest and above all global warming of climate. The threatened species of orchids of various categories is presented in Table 3**.** Although we have huge diversity of orchids in India, neither the actual conservation for the save of this ‘gems’ is yet done properly nor scientific studies carried out under global warming.

Table 1: State wise distribution of orchids in India

Name of the state	Orchids (Number)		Name of the state	Orchids (Number)	
	Genus	Species		Genus	Species
Andaman & Nicobar Islands	59	117	Madhya Pradesh(including Chhattisgarh)	34	89
Andhra Pradesh	33	67	Maharashtra	34	110
Arunachal Pradesh	130	600	Manipur	66	251
Assam	81	191	Meghalaya	98	352
Bihar (including Jharkhand)	36	100	Mizoram	74	246
Chhatisgarh	27	68	Nagaland	63	241
Goa, Daman & Diu	18	29	Orissa	48	129
Gujrat	10	25	Punjab	12	21
Haryana	3	3	Rajasthan	6	10
Himachal Pradesh	24	62	Sikkim	115	496
Jammu & Kashmir	27	51	Tamil Nadu	67	199
Karnataka	52	177	Tripura	33	48
Kerala	77	230	Uttaranchal	72	237

Source: Singh, (2001)

Table 2. Present status orchids in India

Habitat	Species	Endemic	Extinct/ Nearly extinct	Endangered
North Eastern India	675	76	18	34
Eastern Himalayas	730	88	18	105
Western Himalayas	255	10	-	44
Peninsular India	267	13	5	25
Eastern India	130	6	-	5
Andaman & Nicobar Islands	117	15	2	2
Central India & Gangetic plains	60	-	-	-

Orchids are one of the key species in the forest ecosystem. The relationship with forest flora and fauna and dependence for several processes such as pollination, fungal interference, microclimate, dispersal of seeds is well known fact. These complex interdependencies make orchids extremely susceptible to the effects of climate change, deforestation and spread of pesticides. Climate change is considered to be one of the biggest threats to diversity. Anthropogenic pressure and natural calamities like erratic rainfall and unpredictable temperature variation alter the forest ecosystem. The global warming directly affects the structure and composition; growth behaviour; phenology; pollination of orchids. Further, global warming forces the orchids to move upward direction in search of better place for survival. As orchid species are declining at an accelerating pace and as such no mechanism to reverse back the habitat loss to the hot spot area, a protective measure should be taken to restore the species.

Table 3: List of threatened orchid species from India (ICUN Red List 1997)

Sl. No.	Species	States	ICUN Category
1	*Aerides fieldingii*	Assam, Meghalaya, Sikkim	I
2	*Aerides vandara*	Assam, Meghalaya, Nagaland	I
3	*Anoetochilus nicobaricus*	Nicobar Island	E
4	*Anoetochilus rotundifolius*	Tamil Nadu	Ex, E
5	*Anoetochilus sikkimensis*	Sikkim	I
6	*Anoetochilus tetrapterus*	Manipur	V
7	*Aphyllorchis gollani*	Uttar Pradesh	Ex, E
8	*Aphyllorchis vaginata*	Meghalaya	I
9	*Arachnis clarkei*	Arunachal Pradesh, Meghalaya, Sikkim	R
10	*Archineottia microglottis*	Uttar Pradesh	R
11	*Biermannia jainiana*	Arunachal Pradesh	I
12	*Bulbophyllum acutiflorum*	Tamil Nadu	R
13	*Bulbophyllum albidum*	Tamil Nadu	R
14	*Bulbophyllum aureum*	Kerala	R
15	*Bulbophyllum elegantulum*	Karnataka, Tamil Nadu	V
16	*Bulbophyllum fusco-purpureum*	Tamil Nadu	I
17	*Bulbophyllum kaitiense*	Tamil Nadu	V
18	*Bulbophyllum mysorense*	Karnataka	I
19	*Bulbophyllum raui*	Uttar Pradesh	I
20	*Bulbophyllum rothschildianum*	Hills in Northeastern India	E
21	*Bulleyia yunnanensis*	Arunachal Pradesh, Darjeeling (WB)	I
22	*Calanthe alismaefolia*	Arunachal Pradesh, Meghalaya, Uttar Pradesh (Mussoorie)	I
23	*Calanthe alpina*	Sikkim, Uttar Pradesh	R
24	*Calanthe herbacea*	Sikkim	I
25	*Calanthe whiteana*	Sikkim	Ex
26	*Chrysoglossum hallbergii*	Tamil Nadu	I
27	*Cirrhopetalum acutiflorum*	Tamil Nadu	I
28	*Coelogyne angustifolia*	Tamil Nadu	I
29	*Coelogyne barbata*	Meghalaya, Sikkim	I
30	*Coelogyne cristata*	Assam, Meghalaya, Sikkim	R
31	*Coelogyne flaccida*	Meghalaya	I
32	*Coelogyne mossiae*	Kerala, Tamil Nadu	V
33	*Coelogyne nitida*	Assam, Meghalaya, Sikkim	R
34	*Coelogyne prolifera*	Assam, Meghalaya, Nagaland	I
35	*Coelogyne treutleri*	Sikkim	Ex, E
36	*Cymbidium whiteae*	Sikkim	E
37	*Dendrobium arachnites*	India	R
38	*Dendrobium gamblei*	Uttar Pradesh	I
39	*Dendrobium microbulbon*	Gujarat, Maharashtra, Tamil Nadu	I
40	*Dendrobium normale*	Uttar Pradesh	I
41	*Dendrobium pauciflorum*	Sikkim, West Bengal	E
42	*Dendrobium pensile*	Nicobar Islands (Great Nicobar)	I
43	*Dendrobium tenuicaule*	Andaman (Middle Andaman Island)	E
44	*Didiciea cunninghamii*	Sikkim, Uttar Pradesh	E
45	*Diglyphosa macrophylla*	Sikkim	I
46	*Diplomeris pulchella*	Arunachal Pradesh, Meghalaya	I
47	*Disperis monophylla*	Tamil Nadu	I
48	*Epipogium sessanum*	Arunachal Pradesh	I
49	*Eria albiflora*	Tamil Nadu	R
50	*Eria occidentalis*	Uttar Pradesh	R
51	*Eulophia candida*	Assam, Sikkim	I
52	*Eulophia cullenii*	Kerala, Tamil Nadu	I
53	*Eulophia mackinnonii*	Madhya Pradesh, Uttar Pradesh	R

Table 3 Contd..

Sl. No.	Species	States	ICUN Category
54	*Eulophia nicobarica*	Nicobar Islands	E
55	*Eulophia obtuse*	Uttar Pradesh	I
56	*Eulophia ramentacea*	Western Ghats, Gujarat, Karnataka	I
57	*Flickingeria hesperis*	Uttar Pradeah	E
58	*Galeola cathcartii*	Sikkim	I
59	*Galeola falconeri*	Arunachal Pradesh (Kameng), Sikkim, Uttar Pradesh (Garhwal)	I
60	*Galeola lindleyana*	Meghalaya. Nagaland, Sikkim,	I
61	*Gastrodia dyeriana*	Sikkim	I
62	*Gastrodia exilis*	Meghalaya (Jaintia Hills)	I
63	*Goodyera recurva*	Meghalaya (Khasi Hills)	I
64	*Habenaria andamanica*	Andaman (South Andaman Island)	R
65	*Habenaria barnesii*	Kerala, Tamil Nadu	R
66	*Habenaria denticulata*	Tamil Nadu	I
67	*Habenaria fimbriata*	Tamil Nadu	I
68	*Habenaria panchganiensis*	Maharashtra	R
69	*Habenaria polyodon*	Tamil Nadu (Nilgiri Hills)	I
70	*Habenaria richardiana*	Kerala (Travancore), Tamil Nadu	I
71	*Hetaeria ovalifolia*	Kerala, Tamil Nadu (Tirunelveli Hills)	I
72	*Ipsea malabarica*	Kerala (Silent Valley)	E
73	*Liparis beddomei*	Tamil Nadu (Palani Hills)	I
74	*Liparis biloba*	Tamil Nadu (Nilgiri Hills)	I
75	*Liparis duthiei*	Tamil Nadu (Nilgiri Hills)	I
76	*Liparis platyphylla*	Tamil Nadu	I
77	*Liparis pulchella*	Meghalaya, Nagaland	I
78	*Malleola andamanica*	Andaman (South Andaman Island)	E
79	*Neottia kashmiriana*	Jammu & Kashmir	I
80	*Nervilia biflora*	Kerala (Malabar)	I
81	*Nervilia mackinnonii*	Uttar Pradesh (Mussoorie; Kumaun)	I
82	*Oreorchis indica*	Himachal Pradesh, Uttar Pradesh	I
83	*Oreorchis rolfei*	Uttar Pradesh	I
84	*Paphiopedilum druryi*	Kerala (Tranvancore & Kalakkad Hills)	E
85	*Paphiopedilum fairrieanum*	Arunachal Pradesh, Sikkim	E
86	*Paphiopedilum hirsutissimum*	Manipur	R
87	*Paphiopedilum wardii*	E Arunachal Pradesh	R
88	*Peristylus brachyphyllus*	Karnataka, Tamil Nadu	I
89	*Peristylus secundus*	Karnataka, Kerala, Tamil Nadu	I
90	*Phaius mishmensis*	Assam, Meghalaya, Sikkim	I
91	*Phalaenopsis speciosa*	Andaman & Nicobar Islands	E
92	*Pholidota calceata*	Meghalaya (Khasi Hills)	I
93	*Pholidota wattii*	Arunachal Pradesh, Assam	R
94	*Pleione lagenaria*	Meghalaya (Khasi Hills)	Ex
95	*Renanthera imschootiana*	Manipur, Mizoram, Nagaland	E
96	*Rhynchostylis latifolia*	Karnataka	I
97	*Risleya atropurpurea*	Sikkim	I
98	*Taeniophyllum andamanicum*	Andaman Island	E
99	*Vanda coerulea*	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland	R
100	*Vanda wightii*	Tamil Nadu	Ex, E
101	*Vanilla walkeriae*	Karnataka, Kerala, Tamil Nadu	I
102	*Vanilla wightiana*	Kerala	V
103	*Zeuxine andamanica*	Andaman (South Andaman Island)	I
104	*Zeuxine pulchra*	Meghalaya (Khasi Hills), Sikkim	Ex, E
105	*Zeuxine rolfiana*	Andaman (South Andaman Island)	I

Source: Ministry of Environment &Forest, GOI.
Note: E-Endemic; Ex- Extinct; I-Indeterminate; V-Vulnerable; R-Rare

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