Genetic Diversity Conservation and Population Study of Selected Notified Endangered Plant Species of Western Ghats Region of Kerala

(No. 2272/A1/2015/KSBB dt. 19/12/2015)

Project Completion Report

Submitted to

Kerala State Biodiversity Board

Dr. S. William Decruse
Principal Investigator

KSCSTE-JNTBGRI

December 2020

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Final Technical Report
Submitted to

Kerala State Biodiversity Board

Principal Investigator
Dr. S. William Decruse

Co-PI
Dr. M. Rajendraprasad
Co-investigator
Dr. T. Sabu

Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode
Thiruvananthapuram-695562

December 2020

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I. Project Details

Project Title: Restoration/population study of *Paphiopedilum druryi, Vanda wightii, V. thwaitesii, Decalepis arayalpathra* and *Agasthyamalaia pauciflora*, five notified endangered plant species of Western Ghats region of Kerala

Principal Investigator:
Dr. S. William Decruse
Senior Scientist, Biotechnology and Bioinformatics Division
KSCSTE-JNTBGRI

Co- Principal Investigator
Dr. M. Rajendraprasad
Scientist, Plant Systematic and Evolutionary Science
KSCSTE-JNTBGRI

Co-investigator
Dr. T. Sabu
Technical Officer
Garden Management Division
KSCSTE-JNTBGRI

Date of start : March 2016

Project Duration: 4 Years

Date of Conclusion: 31 March 2020

Total Cost: ₹ 20,00,000 (for 4 years)

Total amount released: ₹14,00,000

Project staff-JRF (1)

Mr. Adarsh U.	04-04-2016 to 24-0[illegible]-2017
Mr. Akhil C.A.	22-05-2017 to [illegible]-02-2018
Mr. Sumith S.	2[illegible]-01-2019 to 31-01-2020

2. Project Summary and recommendations

Eight plant species from Western Ghats region of Kerala *viz., Paphiopedilum druryi, Vanda wightii, V. thwaitesii, Decaisnea insignis, Agasthiyamalaia paucifloru, Garcinia indica, Humboldtia unijuga* var *trijuga* and *H. bourdillonii* among the 26 notified species are selected for various conservation efforts as part of the proposal, lasting for four years.

Considerable progress was made during the initial three years, fulfilling almost 80% of the set targets. However, the fourth years' work could not be completed satisfactorily due to unavailability of sufficient balance and not released the fourth instalment. Species wise consolidated report of work carried out in 7 species with conclusions and recommendations based on the present work, previous work and published reports is presented here. *H. bourdillonii* has not been worked out due to limited availability of manpower and workload with 7 other species.

Paphiopedilum druryi : It is a critically endangered orchid species as per IUCN evaluation, 2015. We re-evaluated as per IUCN Guidelines and justified the evaluation 2015 and still it is a critically endangered species. Restoration effort of planting 320 numbers of 2-3 year-old seedlings into its native locality is at experimental stage. Out of the 320seedlings planted in May 2018 at Agasthyamala, 118 individuals survived in spite of delayed summer rains. An *ex situ* conservatory of about 100 plant clumps with 6-25 suckers could be established at JNTBGRI campus. Fruits were produced through hand pollination, obtained viable seeds and germinated to develop into seedlings. Thus a continuous plant production system through the *ex situ* conservatory could be established that can support future restoration and utilization programs. Two plant groups with about 10 suckers each were provided to KSBB museum at Vallakkadavu.

Vanda thwaitesii: Based on field studies as part of the present study and a concluded project, we generated population data and evaluated present status based on IUCN guidelines Version 3.1. *V. thwaitesii* qualified criteria B2a (iii)(iii,iv,v) Version 3.1 to consider under critically endangered category. The restoration efforts of planting 308 seedlings (3 year-old) during 2015 is only partially successful, as only 84 of them in Wyanad and Idukki WLS survived after 3 years. Reinforcement of 2-3 year old seedlings (8641 during 2018-19 both in Wayanad and Idukki WLS showed about 85% establishment. Directlying of seedlings on tree trunk showed better performance compared to those planted on dry bark before reinforcement. As the seedlings were produced through culture of seeds collected from different populations, it is expected that genetic diversity from different populations will establish in Wayanad and

Idukki WLS where small numbers of natural plants are still surviving. More than 600 restored seedlings are expected to be established at both the localities for effective conservation of the species as an initial step in the conservation of *V. travancorica*.

Vanda wightii: The present status of *V. wightii* is evaluated as endangered based on IUCN guidelines Version 3.1 satisfying criteria B2b (i,ii,iii,iv,v). Due to habitat fragmentation, loss of habitat, significant population decline, poor regeneration status and possible shift of ideal habitat towards south, this species may be considered under the latter category. Otherwise it has large population especially in Kasargod District. The plants seem to propagate through vegetative method rather than through seedling recruitment. Severe fragmentation and environmental stress also may affect the decline of the species in that area. The plant distribution model demonstrated extension of suitable habitat towards Western Ghats region in Kollam and Thiruvananthapuram. *V. wightii* seedlings introduced at JNTBGRI campus showed better establishment substantiating the distribution model. Out of 319 seedlings planted, 201 established at JNTBGRI after 5 years with luxuriant growth. *V. wightii* most probably establish a self-perpetuating population at JNTBGRI forests. The restoration made at Idukki WLS was not satisfactory as only 142 out of 357 survived after 1-3 years which is not sufficient to establish the entire genetic diversity of the species. Therefore, reinforcement of genetic diversity from vulnerable localities into other suitable protected habitats like Pongara a buffer zone of Silent valley may be considered for future restoration of diversity from low altitudinal ranges in Palakkad, Malappuram, Kannur and Kasargod districts. At present, we could represent diversity from vulnerable localities through conservation introduction at JNTBGRI campus.

Decaschistia trilobata. Evaluation based on IUCN Guidelines revealed that it can't qualify for inclusion under either critically endangered or endangered criteria. However, the species exhibited slow regeneration in many of the localities and have localized distribution in specific habitats only. Thus it is recommended to consider under **vulnerable** category by criteria B1a, B2a. Out of the 24 location known based on our investigation and published reports, we mapped 9 locations and estimated the population and projected a total of 27,068 mature individuals and 6,803 saplings. Other 5 locations in Kerala region also hold significant number of mature individuals. Significant population decline seems occurred in Sankamotta and easily accessible slopes of Maruthamala para but other populations are intact except isolated attacks from wild boar. Two species of dominant grass belonging to the genera *Germainia* is most common in all locations. The grass anchors the species on barren

rocks during the entire life cycle of *D. aryalpathee*. As most of the populations are in sanctuaries and protected forests, restoration appeared not essential and thus did not attempt for it. Modeling study revealed the presence of suitable habitats extending from Kanyakumari District in Tamil Nadu to hill ranges around Aryankave gap in Kollam district of Kerala. Precipitation seasonality with coefficient of variation 52-62 and temperature mean diurnal range (6.1-7.1) are the most decisive factors for its survival and existence. At least a marginal precipitation throughout the year (64-115mm during Jan-Feb; 281-406mm during March-May; 653-1579 during June-Sept; 551- 765 during Oct-Dec) is essential for the survival of the species.

Hunabohilia unijuga var. trijuga: This species is assessed as critically endangered by IUCN. However, our study revealed good regeneration and spread of the species. The population study facilitated to project a total of over 2000 mature individuals in a perimeter of 2.57Km in a single locality at Chemmunji. But, considering the distribution in a small area the status may be included as endangered based on criteria **C2aii**. The plant distributed locality is Chemmunji hills of Peppara Wildlife sanctuary which is intact and there is no indication of exploitation of the species for any use. Besides, population increase, presence of all life forms and high percentage of plants in the low girth class were observed. Importance Value Index (IVI) was also highest for *H. unijuga* var trijuga in its distribution area at Chemmunji.

Garcinia imberti: *Garcinia imberti* Bourd. was located from the Chemmunji hills of Bonacaord in Peppara Wildlife sanctuary. Based on our study in random quadrates made in the plant distributed area it was clear that *Garcinia imberti* had an IVI of 66.5. It shows that currently Chemmunji hills are safer habitat for *Garcinia imberti*. Trees were distributed in all the girth class but the numbers of higher girth class trees were very less. The presence of high number of trees in lower girth classes indicates good regeneration status in Chemmunji, especially in 40 to 59 and 60 to 89 cm girth classes. As per IUCN categorization, it is an endangered species. Based on our study on its population and published reports we re-evaluated it as a vulnerable species based on criteria **B1a; D2**. The locality of the species under study at Chemmunji is within Peppara Wildlife sanctuary and there is no indication of exploitation or collection for ornamental, medicinal or any other purpose. Besides, there is satisfactory regeneration status in this species as all life forms observed. It has reported distribution in other localities as Bonacord in Peppara W.L.S, Sankhili and Ponmudi in reserve forests of Thiruvananthapuram Forest Division and Poonkulam in Mundanthurai Tiger Reserve in a perimeter of about 72.26 Km with 172,169,358sqm extent of distribution, all are protected forests not having any threat to the habitats.

Agasthiyamalaia pauciflora: We did not undertake detailed investigation in this species. As per IUCN categorization, it is a critically endangered species due to its narrow distribution. Based on our present study in Peppara wildlife sanctuary and an earlier field work in KMTR in addition to published reports we concluded that the species have extent of distribution in 189 Sq.Km area and assigned to Vulnerable category based on criteria **B1+ D2a**. The species is represented by all life forms and the mature trees at low girth category are higher in lathimotta, the location in Peppara WLS we studied in detail. Previous reports also demonstrates, good regeneration status of the species at Kalakkad-Mundanthurai Tiger Reserve especially Nagamalai area.

Recommendations

- Restoration efforts in *P. druryi* need to be continued to ensure its survival in the wild. In such attempts, locations under the canopy of *Euphorbia santapaui* may be preferred over open grasslands.
- Restoration efforts in *Vanda thwaitesii* may be continued to represent populations from localities not covered in the present study ie., from Karnataka. *Dalbergia latifolia* plantations in tribal hamlet, revenue land and under forest Department in Wayanadu hold significant numbers of adult *V. thwaitesii*. Rehabilitation of the population may be encouraged, whenever the trees are removed.
- Large populations of *V. wightii* are present in teak plantations around Ponmudi dam, Idukki reservoir etc. All the plantations belong to Kerala State Forest Department. Rehabilitation of the orchids into protected forests while felling the teak trees should be undertaken. Rehabilitation of diversity from inhabited areas is recommended to conserve entire genetic diversity of low altitudinal ranges, in Palakkad, Malappuram, Kannur and Kasargod districts.
- Restrict extensive collection of *Decalepis arayalpathra* for industrial use. Propagation and cultivation may be encouraged for future industrial applications.
- Due to satisfactory regeneration observed in *D. arayalpathra*, *Humboldtia unijuga var. trijuga*, *Agasthiyamalaia pauciflora* and *Croenia imberti* restoration efforts are not recommended in those species.

3. Technical Report

3.1. Introduction

The Western Ghats, chain of hills running close and parallel to the Arabian Sea along the Western Peninsular India for about 1600 km from the Tapti valley of Gujarat in the north to Kanyakumari in south (Pascal, 1988). The mountain range covers an area of about 160,000 km² totally through the six states Gujarat, Maharashtra, Karnataka, Kerala, Goa and Tamil Nadu (Ramachandra *et al*., 2012). Western Ghats is a rich biodiversity area with high floral and faunal endemism. Figuring in the United Nations Education Scientific and Cultural Organization (UNESCO) World Heritage List in 2012 (Pande and Arora, 2014). Western Ghats along with Sri Lanka considered as one among the 35 biodiversity hotspot of the world (http://www.conservation.org/How/Pages/Hotspots.aspx). It is one among the ten hottest biodiversity hotspots in the world, because of rich biodiversity being threatened by ever increasing human impacts. The Western Ghats is a biological treasure trove which has an inevitable connection with the physiographic evolution. Western Ghats covers only 6 percent of India's total land but it harbors more than 30 percentages of species in the country. Western Ghats harbor nearly 4000 species of flowering plants, of these about 1500 species are endemic. Geographically the Western Ghats classified into 3 major regions such as Surat to Goa, Goa to Nilgiri Mountains and South of the Palghat Gap (Pascal, 1988). When talking about the biodiversity it is more concentrated into the southern region of Western Ghats because of the more favourable climatic conditions luxuriant evergreen forests are present here, the topographic heterogeneity, homogeneity in rainfall distribution and lesser dry period of about 3-4 months closely interlinked to the biodiversity of southern Western Ghats. The last bit of south of Palghat Gap, the Agasthyamala range is very rugged and the region has high endemism and diversity in the Ghats.

This unique eco-system has been threatened by continuously increasing habitat pressures. From time immemorial, forests of Western Ghats pass through various pressures both natural and manmade. But the ever increasing human population and needs placed enormous pressure on the biodiversity of the Western Ghats. Urbanization, clear felling of natural forests, habitat destruction, over exploitation, illegal wildlife trade, pollution and climate change lead to species extinction in Western Ghats. Currently biodiversity has attracted world attention because of its importance and rapid ongoing depletion.

The project entitled "Genetic diversity conservation and population study of selected notified endangered plant species of Western Ghats region of Kerala" concerned about eight plant

species of Southern Western Ghats region of Kerala (Table 1, Figs 1-8). These species were notified by Government of India as endangered (MOEF, 2009).

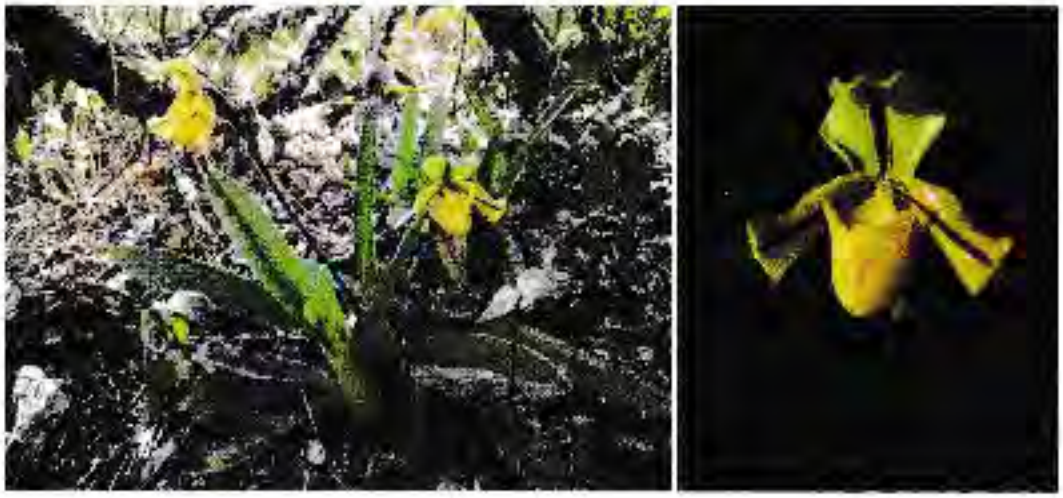

Fig 1. *Paphiopedilum druryi*., in its native locality at Agasthyamalai

Fig 2. *Vanda wightii*, habit

Table 1. Plant species selected for the present investigation

Sl. No	Species	Distribution	Current status (IUCN/ MOEF, India)
1	*Paphiopedilum druryi* (Bedd.) Stein	Agasthyamalai region belonging to Peppara, Neyyar and Kalakkad-Mundanthurai sanctuaries	Critically Endangered (IUCN)
2	*Vanda wightii* Rchb.f.	Western Ghats in Kerala, Karnataka and Goa in India and SriLanka	Endangered (MOEF)
3	*Vanda thwaitesii* Hook.f.	Western Ghats in Kerala, Karnataka and Tamil Nadu in India and SriLanka	Endangered (MOEF)
4	*Decaisnea aravalpathra* J. Joseph & Chandras	Western Ghats in Southern parts of Kerala	Endangered (MOEF)
5	*Agasthiyamalaia pauciflora* (Bedd.) S. Rajkumar & Janarth.	Peppara WLS in Kerala and KMTR in Tamil Nadu	Critically Endangered (IUCN)
6	*Garcinia imberti* Bourd.	Chemmunji hill and Ponmudi in Tvm District, Kerala	Endangered (IUCN)
7	*Humboldtia unijuga* Beddome var. *trijuga* Joseph & Chandras	Chemmunji hill in Thiruvananthapuram District, Kerala	Critically Endangered (IUCN)
8	*Humboldtia bourdillonii* Prain	Sabarimala of Periyar Tiger Reserve, Kerala	Endangered (IUCN)

Fig. 3 *Vanda thwaitesii* Hook.f.

Fig 4. *Decalepis arayalpathra*, habit

Fig 5. *Garcenia imberti*, habit

Fig 6. *Agasthivannalaja pauciflora*, habit

Fig 7. *Humboldtia unijuga* var trijuga. habit

Fig 8. *Humboldtia bourdillonii*. habit

3.2. Case studies

3.2.1 Paphiopedilum druryi

3.2.1.1 Description

The Indian slipper orchid *Paphiopedilum druryi* (Bedd.) Stein probably the only one among an estimated 60 species of the genus *Paphiopedilum* completely isolated in distribution to the extreme southern ranges of the Western Ghats after the Pleistocene era (Delden, 1971). Originally found in great profusion in the so called Travancore Hills and collected by Mrs. J. A. Brown in 1865 (Cribb, 1978 & 1987) it remained obscure to the botanical world for more than a century until Mammen and Mammen (1974) relocated a solitary colony of the same in Agasthyamalai. The latter authors authenticated its distribution at an altitude of 1350-1600 m in hard limy soil in the windward side of the mountain falling under Peppara Wild Life Sanctuary and refuted its reported occurrence at lower elevations in the nearby Kalakkad hills (Delden, 1971). Pampahishey (1976) described a sponsored collection trip in which a few tiny plants were apparently collected from the same habitat but subsequently the species was described as endangered or extinct in the wild (Knees, 1988). Frequent forest fires and consequent habitat destruction (Mammen and Mammen, 1974) and over collection for ornamental and medicinal purposes (Pradhan, 1978) are attributed to its decline in the native habitat. At presen *P. druryi* is protected from export by national legislation, included in IUCN Plant Red Data Book (Ramkan and Kumar, 2015) as critically endangered. In response to Government of India's request to gain extra protection for those still surviving in the wild it was inducted in Appendix-I of the Convention on International Trade of Endangered Species of wild flora and fauna (Knees, 1988).

3.2.1.2 Distribution

The species have narrow distribution in Agasthyamalai falling under Peppara wildlife sanctuary, and Neyyar Wildlife sanctuary in Kerala and Kalakkad-Mundanthura tiger reserve in Tamil Nadu

3.2.1.3 Population information

A population study conducted in March 1993 (Menon et al 1995) revealed 1126 plant groups each with 1-35 shoots surviving at Agasthyamala region belonging to Neyyar Wildlife sanctuary. The Plants growing under partial shade provided by *Dipla sp. Syzygium*

sp. *Osbeckia* sp, *Melastoma* sp., *Lenheria sebastiana* etc. were healthier with newer growths than those growing in the open. In spite of the fairly large population size, only seven seedlings could be noticed in the plot. Most of the plants were under the partial shade of the stunted trees and shrubs in the forest border. However, the plants are not distributed inside the forest.

3.2.1.4 Habit and Habitat

H. aruvi inhabit withered rocks or thin sandy loam type soil in the plains or in the slope montane grass lands often in partial shade provided by tall grasses, shrubs or small trees. The trees adjacent to the habitats were short owing to high velocity winds to which they were constantly exposed. The roots of the plants are tightly packed and embedded in the top layer of the soil. The long branched rhizomes of the plants are creeping at shallow 0.3-2 cm depth and remained at times partially exposed on the ground. Number of suckers per plants mostly ranged between 3-20. The rhizomes of certain mature plants extend to 130 cm long with up to 35 suckers. The plants found in partial shade are robust and vigorously growing compared to others exposed to open sun. The leaves of the healthy plants are 20-30 cm long and 2.5–4 cm wide while those of the weaker plants in the open are short (8-14 cm) and narrow (1.8-3 cm). Peak flowering of the plants is in March and each flowering plant has at least three suckers, out of which the oldest one often have the flower. After the complete opening of the flower, a new sucker invariably emerge from the basal part of the youngest sucker and grew vigorously as the flower got withered and the flowering shoot lost its growth any further. Thus even after the drying up of the flowering sucker, in most cases, the plants maintained three individual shoots at various stages of development. In some plants, after years of growth, there were several shoots arising through branching of rhizome, of which the oldest of the three suckers have flowers. In such plants, increase in the number of plants is through vegetative means by drying and decaying of the rhizome at certain parts and subsequent separation and development of the shoots into individual plants.

3.2.1.5 Decline and threat

Population study conducted in 1993 (Menon et al 1995) revealed the presence of 1126 plants each with 3-25 suckers in one locality and a few more plants within a radius of about 2Km. However, a survey made in 2019 revealed the presence of approximate 250 plant groups each with 2-7 suckers (Fig. 9). Number of suckers per plant is also less in the remaining plants. Thus 78% of the population in plant groups and 90% of the population by individual suckers

was lost in 25 years. Anthropogenic pressures and disturbance of wild animals are the possible factors influencing the population decline.

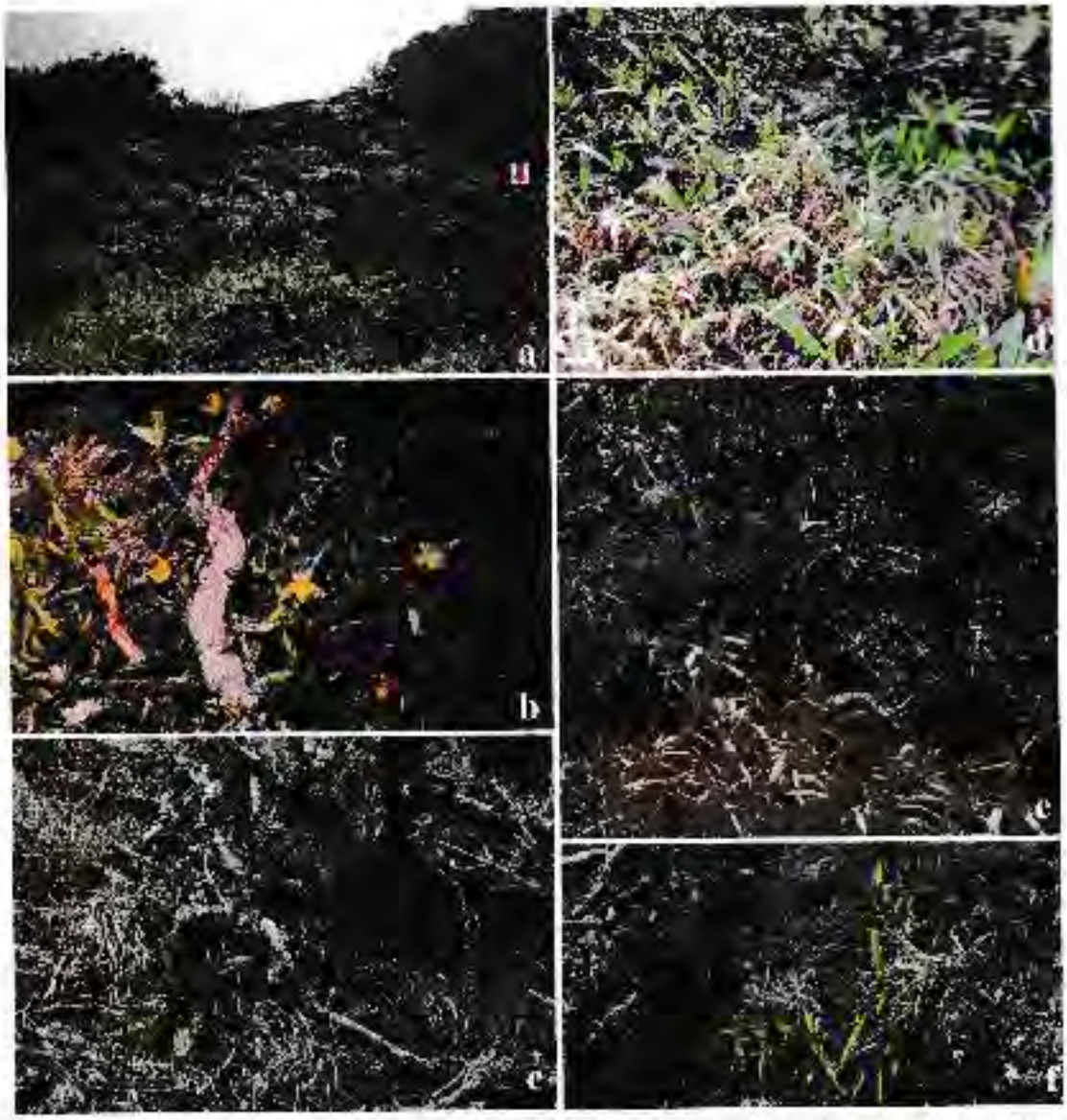

Fig 9. *Paphiopedilum druryi* in its native locality at druryi para of Agasthyamalai, in Neyyar Wildlife sanctuary. a-c. a plot with maximum number of plants observed in 1993. a. in August 1993. b. in April 1993, c. in April 2019; d-f. a plot with maximum density observed in August 1993 (d) and in April 2019 (e,f)

3.2.1.6 Status as per IUCN evaluation 2015 (Rankou & Kumar 2015)

Assessment Information (Rankou & Kumar 2015)

Red List Category &Criteria: Critically Endangered **A2abcd+3bcd+4abcd;**

B1ab(ii,iii,v)+2ab(ii,iii,v); C1 ver 3.1

Year Published: 2015; **Date Assessed:** October 17, 2014

Justification: Global assessment: **Critically Endangered (CR)**

Paphiopedilum druryi is very local and very rare with a restricted distribution on the Agastamalaya Hills. There were five localities according to Manon *et al.* (1995), whereas in 2001 Kumar *et al.* (2001) reported only three subpopulations. The trend of the population is decreasing and the abundance of the species has been significantly reduced in recent decades. Many subpopulations have been stripped quickly due to threats including ruthless collection for regional and international trade, exploitation for horticultural and medicinal purposes, habitat degradation, human disturbance, trampling, deforestation, fires and tourism. The estimated extent of occurrence and the area of occupancy of the species is 4 km2 with an estimated continuing decline in the number of mature individuals and the quality of habitat. There has been drastic decline in the population size, as well as the number of subpopulations. The habitat is fragmented and the number of mature individuals left in the wild is less than 250. The rate of decline is 90% in the past three generations and there is a projected decline of 90% in the next three generations. The species is projected to become extinct in the wild within the next 100 years.

Therefore, *Paphiopedilum druryii* is assessed as Critically Endangered (CR).

Geographic Range

Range Description

Paphiopedilum druryi is endemic to southern India in Kerala and Tamil Nadu (Cribb 1998, Kumar *et al.* 2001, Chowdhury 2004, Pridgeon *et al.* 2009). The extent of occurrence and the area of occupancy are estimated at 4 km2. The species is found between 1,400 and 1,550 m asl.

Country Occurrence: Native: India (Kerala, Tamil Nadu)

Population

The trend of the population size is decreasing (Cribb 1998, Kumar *et al.* 2001). The habitat is fragmented and the number of mature individuals was 3,459 according to Manon *et al.* (1995) and less than 250 mature individuals according to Kumar *et al.* (2001). The rate of decline is 90% in past three generations and the species is projected to become extinct in the wild within the next 100 years.

Current Population Trend: Decreasing

Habitat and Ecology

Paphiopedilum druryi grows in xerophytic habitat on southeastern and southwestern facing slopes between 1,400-1,550 m asl in thin sandy loam (pH 4.6 – 5.5) in montane grassland with scattered shrubs and small trees on weathered rocks. The known habitat ranges from 20 to 1,500 m2. It can tolerate full sunshine during March and April in flowering season (Menon *et al.* 1995, Pridgeon *et al.* 2009). The species is always found growing in association with the endemic grass *Zenkeria sebastinei* (Kumar *et al.* 2001). Menon *et al.* (1995) did some

ecological studies in Kerala on seven subpopulations on the Agasthiamalaya hills. The maximum generation length is 10 years.

Systems: Terrestrial

Use and Trade

Paphiopedilum druryi is known to be used in horticulture and there are reports of this plant being used in herbal medicine (Maridassa *et al.* 2008).

Threats

Paphiopedilum druryi is under numerous threats especially ruthless collection for regional and international trade (most of the localities are quickly stripped), exploitation for horticultural purposes, habitat degradation, human disturbance, trampling and forest fires which are common in the upper parts of Agasthiamalaya hills. Although it is not confirmed, there have been reports of ethnomedicinal use of this species (Maridassa *et al.* 2008). There are many scenic areas and temples on the hill and hence another major threat is tourism as this hill is visited by religious followers as well as tourists. They stay in tents and are one of the main causes of habitat degradation, as well as forest fires. Apart from these, landslide is also a threat (Kumar *et al.* 2001). The species is threatened more generally by climate change and the intrinsic factors of the species.

3.2.1.7 Present Evaluation as per IUCN Guidelines (Annexure-I)

At present, the species is evaluated as critically endangered based on criteria **A2a,c,d+ A3a,d+ B1a+b(ii+iii+v)+ B2a+b(ii,iii,v) + C1+2a(i+aii) version 3.1** A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E (Annexure-I) and it is therefore considered to be facing an extremely high risk of extinction in the wild;

Assessment information:

- There is severe decline of population by 78-92% among 2 subpopulations evaluated through direct observation **(A2a,c,d)**
- There is suspected population reduction in 10years evaluated through direct observation **(A3a,d)**
- Extent of occurrence is only 4Km^2. Population identified in one locality with 2 sub-populations at distance 2Km. **B1a+bii+biii+bv**
- Area of occupancy about 0.2SqKm; **B2a+2bii,iii,v**
- Population size more than 250 mature individuals. Continuing decline. One population hold more than 90% of the individuals. **C1+2a(i+aii)**
- Quantitative analysis not undertaken as there is 50% probability of extinction in the wild within 10-20years based on our observations since 1992.

Conclusion: *Paphipidelium druryi* come under **Critically Endangered** Category based on criteria **A2a,c,d+ A3a,d+ B1a+b(ii+iii+v)+ B2a+b(ii,iii,v) + C1+2a(i+ii)**

Thus the IUCN assessment in 2015 is justified and the causes are still continuing

3.2.1.8 Conservation action: Reintroduction/Reinforcement

3.2.1.8.1 Methodology

It include collection of mature capsules from their native locality, seed culture, hardening and rearing of seedlings in the nursery for 2-3 years, co-cultivation with natural soil/substratum possessing symbiotic fungus and planting in into their native localities. The seedlings were raised as part of previously concluded projects supported by DBT, Government of India ("National Programme on Recovery of red-listed species (*Coscinium fenestratum, Paphiopedilum druryi, Dialium travancoricum* and *Pneudemonron pauciflorum*) through application of biotechnological tools", 2006-2012. For reference purpose, method of propagation is briefed here.

Seed culture

Capsules of approximate 11 month maturity measuring 4.0 cm long and 1.2 cm wide (Fig. 10a) possessing 80.32% seeds with fully formed embryos (Fig.10b) are proved better for seed culture.

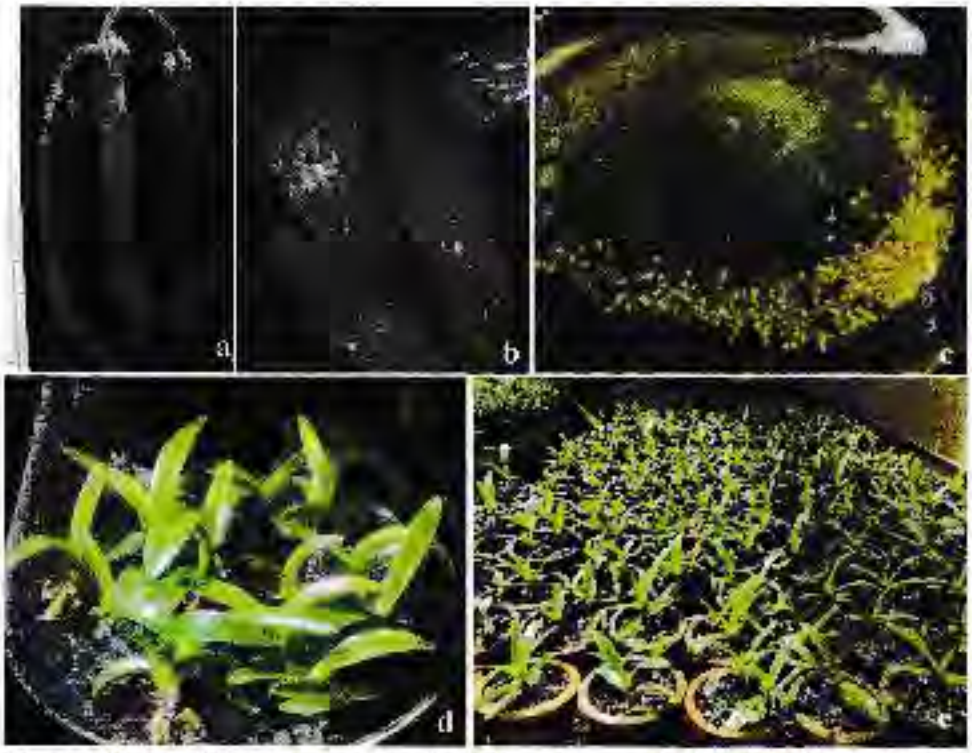

Fig 10. Seed culture of *Paphiopedilum druryii*. **a.** 11 month old capsule; b. seeds; c. Protocorms developed in Mitra et al + CH (0.05%) liquid medium after 60 days; d. Seedlings developed through subculture of protocorms in agar gelled WPM+0.05% activated charcoal medium; e. Seedlings hardened in the nursery, after one year.

Media: Mitra *et al.* (1976) medium supplemented with CH (0.05%) is ideal for seed germination and protocorm growth (Fig. 10c). Subculture of protocorms into WPM medium (Lloyed and McCown 1980) containing 0.6% agar and 0.05% activated charcoal give better growth of seedlings (Fig 10d)

Surface sterilization and inoculation: Wash the capsules (collected before dehiscence) thoroughly in running tap water using labolene. and submerge in 0.1% $HgCl_2$ for 7 min. Dip the capsules in alcohol. flame for 2-3 sec and place in a sterile petriplate. Cut open the capsules under a luminar airflow and transfer the seeds into 250 ml conical flasks containing about 60 ml pre-sterilized liquid media. Examine a sample of seeds under microscope to confirm the presence of viable seeds (seeds possessing fully formed embryos, Fig. 10b).

Culture: Incubate the cultures in a culture room illuminated with cool fluorescent tubes room and swirling of the flasks manually once in a day. Germination may be assessed at 15 day intervals. Seed germination is visible after about 30 days of inoculation as evidenced from the swelling of seeds and growth into protocorms (Fig. 10c). An average 50% (appx) of the seeds may be germinated even though 80.3% of the seeds possess fully formed embryos.

Subculture: Subculture the protocorms obtained after 90 days of culture in WPM containing 0.6% agar.

90-day old protocorms (protocorms obtained after 90 days of seed culture in liquid Mitra *et al* medium) transferred to WPM supplemented with charcoal turns dark green and developed into bigger protocorms and develop shoot initials in 30-45 days. They develop into shoots with 3-4 leaves and 3-5 roots in 6 months period when they are ready for *ex vitro* hardening and transfer into nursery.

Nursery establishment: De-flasked seedlings transferred to a mist house (misting lasting for 30s at 1-3h intervals depending on season) in a potting mixture of coarse river sand neopeat (3:1) is ideal for early hardening of the seedlings. After initial hardening for 30-60days, transplanted the seedlings into a potting mixture containing coarse sand extracted from JNTBGRI forest pavements (It also contains dry leaf debris and microflora), charcoal granules and vermicompost (6:2:1) for better growth and establishment (Fig 10e) as in the natural habitat without any external application of chemical fertilizers. The seedlings reared in the nursery for 2 years were repotted (Forest sand, dry leaf powder, biochar) and reared further for 2 years for restoration as part of the present investigation.

Isolation and Characterization of symbiotic fungus and utilization in restoration

Culture of root segments with endomycorrhiza colonization (Figs 11a & b) from seedlings on FIM (Clements et al 1986), mycelia grown out from the root segments separated and purified through single tip culture. Most useful strain identified through co-culture with seedlings under *in vitro* conditions and evaluated their efficiency to support field establishment.

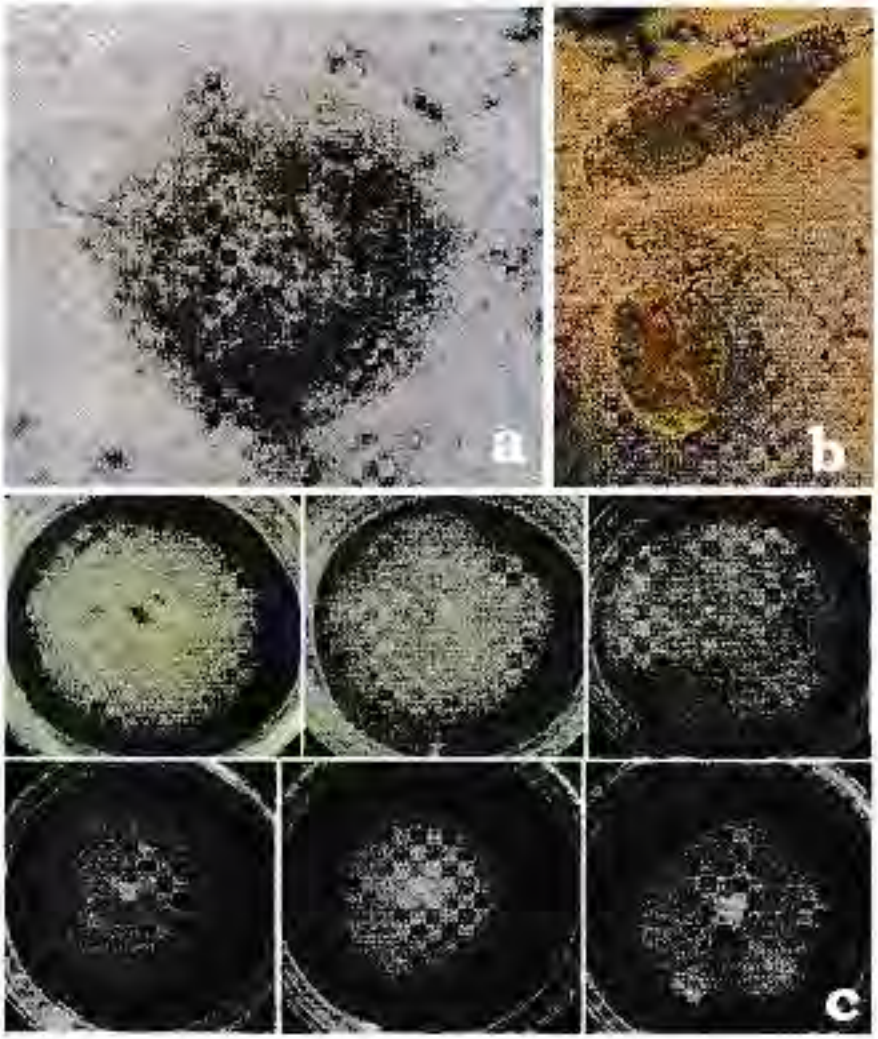

Fig. 11. a. TS of seedling root of *P. druryii* showing mycorrhizal colonization: b. Isolated pelotom from *P. druryii* roots; c. The isolated strains of endomycorrhiza maintained in PDA medium.

Reintroduction: Reintroduction made at Pongalappara in Agasthyamala, its native locality. Once the species was abundant in this area but later (after 1979) it disappeared from this locality. Small pits were made in the rocky exposures covered with grasses other than *Zeitheria sebastiana*. Surrounding vegetation was not removed and the seedlings were planted in groups of 10-30 numbers. Locations in shola boundaries, slopes and under the shade of *Euphorbia santapaui* were selected to mimic druryi's natural habitat.

3.2.1.8.2 Achievements

3.2.1.8.2.1 Isolation and Characterization of symbiotic fungus and utilization in restoration

Six strains (isolates) of symbiotic fungus (Fig 11e) were isolated from the hardened seedlings of *P. dranyi* in fungal isolation medium (Clements *et al* 1986). They were differentiated by growth characters and development of moniloid cells. The fungus strains were also tested for their symbiotic activity by co-culture with seeds of *P. dranyi* . One strain gave positive results so that two seeds germinated symbiotically and developed into seedlings (Fig 12).

Fig 12 Symbiotically germinated seedlings of *P. dranyi*.. with one strain isolated from its roots

3.2.1.8.2.2 Restoration

320 Seedlings of *P. dranyi* after 4 years growth in the nursery were planted into its natural locality in Agasthyamala as part of its restoration. The plants were categorized as three groups based on their growth stage. The first group possessed up to 10 leaves and was having an average 30cm height (Fig 13a). The second group possessed up to 8 leaves and was with an average height of 20 cm (Fig 13b). The third group has an average 15 cm height and 4-7 leaves (Fig 13c). The plants were uprooted without damaging the roots, groups of 10 wrapped in newspaper, slightly wetted, packed in rice bags and transported to the localities in 2-3 days.

Fig 13a,b. Seedlings of *Paphiopedilum druryi* (Category-1 and 2) taken for restoration

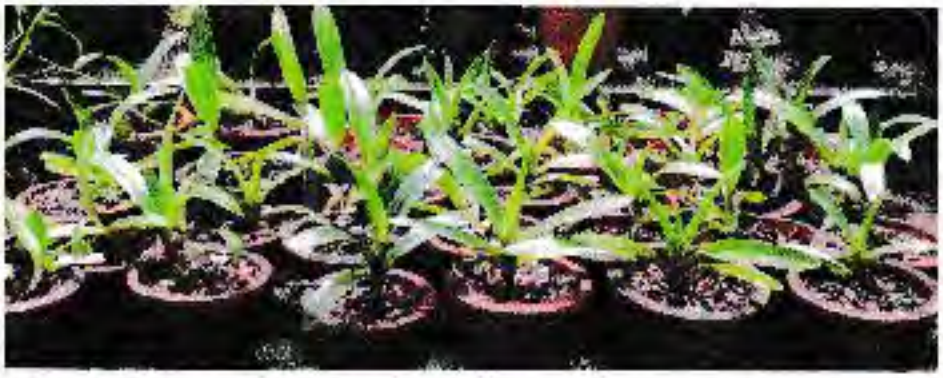

Fig 13c. Seedlings of *Paphiopedilum druryi* (Category-3) taken for restoration

Fig 14. Google earth view of Agasthyamala and the restoration localities

Two locations in Agasthyamala viz., druri para in Neyyar wildlife sanctuary and Pongalappara in Peppara wildlife sanctuary were selected for restoration (Fig 14). In druri para, a small population (Fig 15a) is still surviving but in the type locality, Pongalappara the

species was completely disappeared long back due to indiscriminate collection. Small pits (Fig 15b) were made in the rocky exposures covered with grasses in its native locality in druryii para. A few plants were planted under the shade of *Euphorbia santapaui* (Fig 15d) in pongalappara and close to sholas of stunted trees/shrubs (Fig 15c) in both localities. The seedlings were planted in groups of 10-30 numbers (Figs 16a-g). Planting was done in May 2018 after getting sufficient summer rains. The soil was wet and fresh associate vegetation as grasses, herbs and small shrubs completely occupied the *P. druryi* localities (Figs 16a-g).

Fig 15. Restoration locations a. surviving plants in the native locality; b. Small pits made in grass land. c. restoration made in grassland slope very close to a shola; d. Restoration under the canopy of *Euphorbia santapaui*.

Fig 16 a,b. Restoration of *P. druryi* at Agasthyamalai on 16th and 17th May 2018

Fig 16 e-g. Restoration of *P. druryi* at Agasthyamalai on 16th and 17th May 2018

When monitored in 3rd and 4th April 2019, the area was completely dry due to delayed summer rains. After the early withdrawal of North East Monsoon in November 2018, the Agasthyamala region did not receive rains until 4th April, when we monitored the restored populations. The natural populations were found struggling to survive (Fig 17). The grass lands dried up completely including shrubs (Figs 18a). Therefore, only a few plants planted in the open grass lands (Figs 18b & c) in druryi para survived with a few leaves dried up.

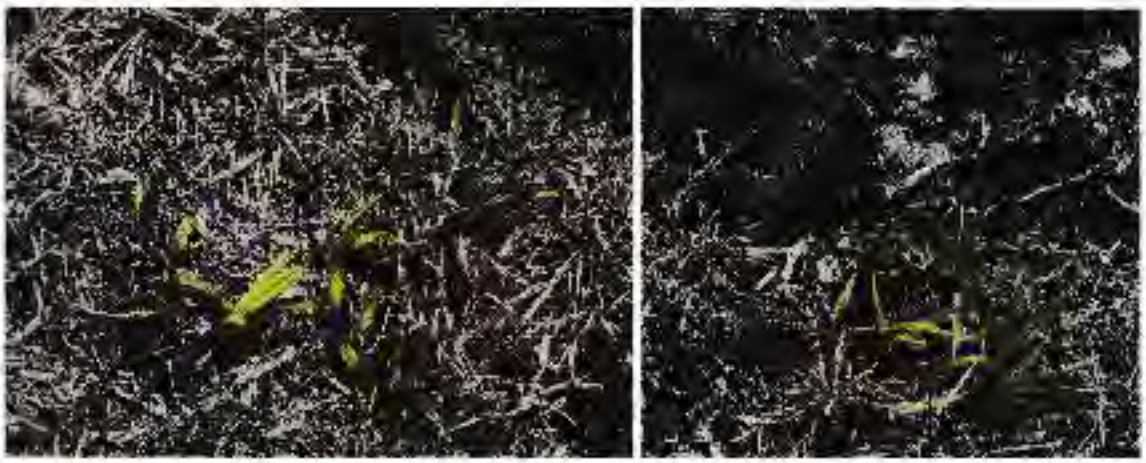

Fig 17. Native population of *P. druryi* in April 2019, after a long dry period

However, a few seedlings planted in rock crevices looked healthy probably due to masking of sun in the afternoon (Fig 18d).

Fig 18. Locations in Agasthyamala where *P. dunyi* were planted in May 2018 and observed in April 2019. a. a shrubby grassland; b,c survived plants in the grassland with shrubs; d. survived plant very close to a rock.

Seedlings planted under the shade of *Euphorbia sanapoui* (Fig 19c) and close to shola edges (Fig 19a) in Pongalappara looked green and healthy. Also, seedlings planted in grass land of a hill slope in Pongalappara (N8 37.296 E77 14.580) where the possibility of mist fall is high also showed higher survival (Fig 19b,c,d). There is no other specific adaption of the seedlings with regards to growth stages or locations (Table 2). The only limitation seems to be wetness of the soil. The data suggest that Pongalappara is better than druri para for better survival, even after extreme dry condition.

Fig 19. Restored plants of *P. dunyi* after one year of planting, April 2019. a. Seedlings planted close to a shola; b seedlings planted in a misty hill at Pongalappara

Fig 19. Restored plants of *P. druryi* after one year of planting. April 2019. c-d seedlings planted in a misty hill at Pongalaparai; e. Seedlings planted under the canopy of *E. sontapaui*.

Table 2. Restoration of *Paphiopedilum druryi* at Agastyamala

Plant Category*	Position	Location	Planted 16-05-18	Survived 16-04- 2019	
C1; Plot 1	N8 36.726 E77 14.431	Druri para	30	14	
C2; P1	N8 36.661 E77 14.435	Druri para	20	6	
C3; P1	N8 36 660 E77 14.432	Druri para	20	3	
C1; P1	N8 36.667 E77 14.427	Druri para	20	9	
C1; P3	N8 36.651 E77 14.433	Druri para	20	6	
C1; P4.1	N8 36.725 E77 14.394	Druri para	10	3	
C1; P4.2	N8 36.720 E77 14.4 0	Druri para	10	3	
C1; P4.3	N8 36.712 E77 14.420	Druri para	10	6	
C2; P2	N8 37.280 E77 14.47	Pongala para	50	11	
C3; P2	N8 37.289 E77 14.497	Pongala para	30	5	
C3; P3	N8 37 289 E77 14.576	Pongala para	20	2	
C1; P5	N8 37.296 E77 14.580	Pongala para	20	15	
C2; P3	N8 37.302 E77 14.584	Pongala para	20	11	
C2; P4	N8 37.312 E77 14.6 2	Pongala para	20	9	
C3; P4	N8 37.312 E77 14.6 2	Pongala para	20	15	
Total			320	118	36.8%

*C1,C2,C3- Three growth stages of seedlings used for restoration
P1-5- Plots in the respective location

3.2.1.8.2.3 *Ex situ* conservatory

About 75 pots each with 3-30 suckers are maintained in an *ex situ* conservatory at JNTBGRI campus at an altitude 180m above mean sea level. The plants get acclimatized at the lower altitude compared to 1400-1800m in their native habitat as evidenced by their luxuriant growth and consistent flowering every year. A group of about 40 plants flowered in January 2019 which was observed as the peak flowering (Fig 20) when recorded fall in night temperature below 18^{0}C. The plants flowers during December-January every year since 2014. In the natural locality in Agasthyamala, it flowers during the months of March May. Natural fruit set is not consistent. However, fruit set with viable seed formation could be obtained through hand pollination (Fig 21). Seeds thus produced could be germinated to produce seedlings. Thus a continuous plant production system could be established through the *ex situ* conservatory.

Fig 20. *Paphiopedilum druryi* at the *ex situ* conservatory of JNTBGRI

Fig 21. Fruit set obtained through hand pollination in mother plants maintained in the *ex situ* conservatory at JNTBGRI

3.2.1.8.2.4 Conclusion

Based on the study at the native localities we noticed that the population decline is still continuing. Thus based on our population study, we re-evaluated as per IUCN Guidelines and justified the evaluation 2015 and concluded that *P. druryi* will continue as a critically endangered species. Our restoration effort of planting 320 numbers of 2-3 year-old seedlings into its native locality is at experimental stage. Out of the 320seedlings planted in May 2018 at Agasthyamala, 118 individuals survived in spite of delayed summer rains (no rain from November to April). We expected high survival rate as the seedlings already established symbiotic association with compatible fungus. However, an *ex situ* conservatory of about 100 plant clumps with 6-25 suckers could be established at JNTBGRI campus. They flower every year in January. Fruits could be produced through hand pollination to get viable seeds that germinated *in vitro* and developed into seedlings. Thus a continuous plant production system through the *ex situ* conservatory could be established that can support future restoration and utilization programs.

3.2.2 *Vanda thwaitesii* J.D. Hook

3.2.2.1 Description

Vanda thwaitesii was first collected by Thwaites from Sri-Lank. Hooker in 1898 described the species and named as *Vanda thwaitesii*, after its collector (Sathishkumar and Sureshkumar 1998). *V. thwaitesii* remained elusive for over a century which forced Jayaweera in 1981 to declare the species as extinct (Sathishkumar and Sureshkumar 1998). During 1982 to 1997 period, the species was collected from Silent Valley and Wayanad thus confirming their presence in India (Sathishkumar and Sureshkumar 1998). The latter authors could also locate reference of *V. thwaitesii* collected in 1885 from Manantbavady in Wayanad District of Kerala. As per reports, the species have distribution in 7 localities in Kerala. The species is described as distributed in narrow pockets with restricted numbers and later under section 38 of the Biological Diversity Act 2002, the Central Government notified that *V. thwaitesii* is on the verge of extinction and prohibited/regulated collection along with other 25 plant species from Western Ghats (MOEF, 2009). The ministry also called for studies on all aspects of the notified species for holistic understanding and propagation of the species for the purpose of *in situ* and *ex situ* conservation and rehabilitation.

V. thwaitesii can be distinguished by its curved keeled leaves with flowers having deeply orange petals and creamy white lips with 8 deep orange lines. The flowers have sweet fragrance as that of *Mimusops elengi*.

3.2.2.2 Distribution

It is an epiphytic orchid which is endemic to the Western Ghats in the states of Kerala, Tamil Nadu and Karnataka at 500-1060m altitudes in moist deciduous to evergreen forests as per the reports (Table 3; Sathishkumar *et al.*, 1998).

Table 3. Distribution of *V. thwaitesii* as per cited literature (Sathishkumar and Sureshkumar 1998)

Locality	State/ Country	Citation/collection
Gunnasgiria	Sri Lanka	1898
Silent Valley	Kerala, India	1982
Lakkidi	Wayanadu, Kerala	1987
Onodayangadi	Wayandadu, Kerala	1997
Thirumelli	Wayandadu, Kerala	1997
Periya	Wayandadu, Kerala	1998
Manathavady	Wayandadu, Kerala	1995
Periyar Tiger Reserve	Idukki, Kerala	Jomy Agustine 1995 (Kew record)

Extended distribution (Fig 22) of the species was revealed by ecological niche modeling followed by model based surveys as part of a previous project supported by DBT, Govt. of India (JNTBGRI 2016). It shows the distribution of the species in Coorg district of Karnataka, Nilgiri districts of Tamil Nadu, Kannur District of Kerrala, Idukki Wildlife sanctuary and several locations in Wayanadu in addition to the reported localities (Figs 22). The distribution extends to a stretch of about 410KM, covering an area of 4792Km^2 (by joining the occurence points). The potential habitats extend from Agasthyamalai in Thiruvananthapuram District of Kerala/Thirunelveli District TN to Bhadra WLS in Chickmangallur district of Karnataka.

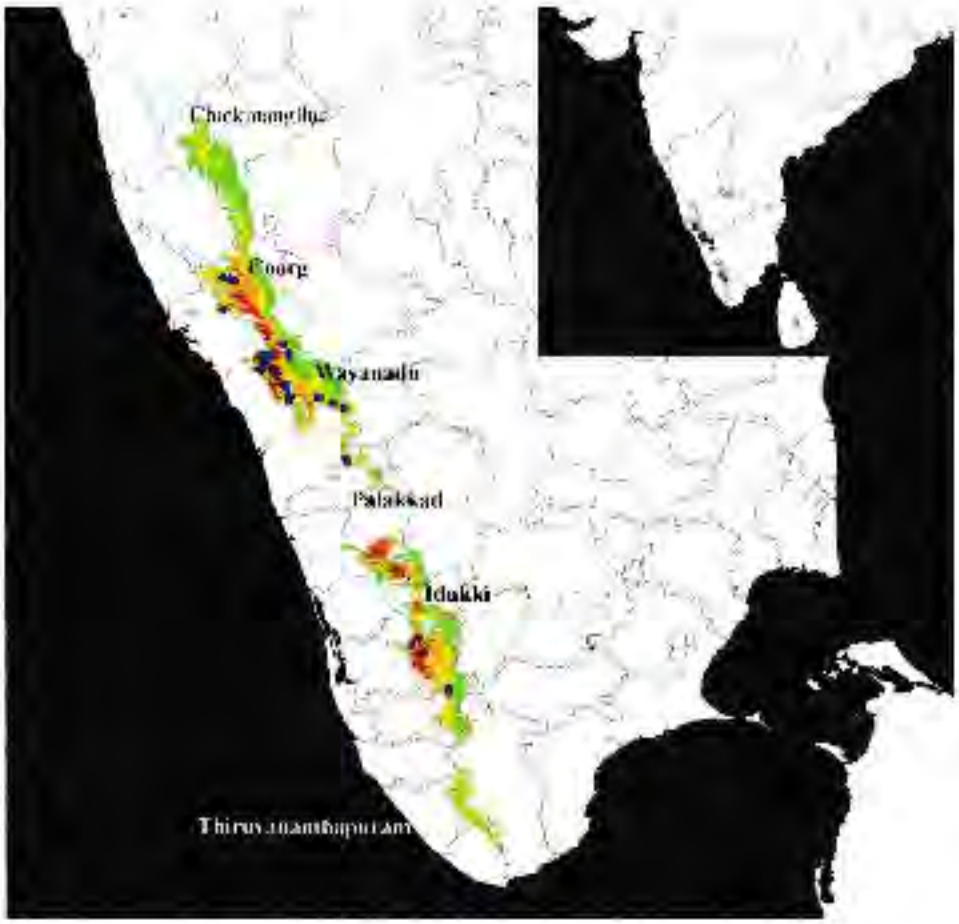

Fig 22. Distribution of *Vanda thwaitesii* (Blue spots) overlaid on a distribution model generated using maxent modeling software.

3.2.2.3 Population information

A detailed study have been made as part of a project supported by DBT during 2010-16 period (JNTBGRI, 2016) which revealed significant number of individuals are surviving in Wayanad and Idukki districts of Kerala. Out of the 1183 individuals scored from the 3 States.

625 were in Wayanadu. Only small populations were reported from protected forests as Idukki Wildlife sanctuary (21), Periyar Tiger Reserve (70) and Silent Valley National Park. Fruit set and seedling recruitment are significant in Wayanadu but was negligible in Periyar Tiger Reserve.

3.2.2.4 Habit and Habitat

V. thwaitesii is an epiphytic orchid, inhabiting mainly on *Mangifera indica* and rarely on *Elaeocarpus tuberculatus* as host at 500-1000m altitudes in moist deciduous to evergreen forests, as per the reports (Sathishkumar *et al.*, 1998). Actually they used to inhabit diverse hosts common to moist deciduous to evergreen forests, like *Mangifera indica, Gmelina arborea, Ficus religiosa, Tectona gandis, Dalbergia latifolia, Persea macrantha, Careya arborea* and *Dysoxylum malabaricum*. Trees like *Spathodea companulata, Artocarpus heterophyllus*, and *Pterocarpus marsupium* also serves as host in some localities.

3.2.2.5 Decline and threat

Out of the total 1183 individuals of *V. thwaitesii* scored as part of a previous study, 12.7% (111) was in protected forests and 145 individuals (16.5% of total) in *Dalbergia* plantations in tribal hamlets, revenue land and disturbed forest. The populations in Idukki WLS, Thirunelli (Begur Range, Wayanad North Division) and Periyar Tiger Reserve are safe and no special conservation action required. In other places in Wayanad, Coorg and Nilgiri districts 619 individuals (70.7% of the total) were observed along highways and inhabited land and thus are highly vulnerable to genetic loss. Therefore, their population with appreciable floral diversity is not safe in their native localities. Significant numbers of fruits (133) and new recruits were also observed but most of them were in the inhabited locations. Thus it is evident that there are no reproductive problems and seed germination exists. Therefore, habit destruction/fragmentation is the main reason for the population decline and spread of the species. In addition, diversity analysis also revealed very low heterogenity and gene flow. Thus the population is at high risk of endangerment/extinction. Propagation of the diversity in inhabited land and reinforcement into safe localities are thus essential to conserve the entire genetic diversity of *V.thwaitesii*.

This species even though notified by Government of India, not so far included in the IUCN red data book. Therefore, it is assessed as per IUCN Guidelines (Annexure-1)

3.2.2.6 Assessment of threat status based on IUCN guidelines

***V. thwaitesii* is evaluated as Critically Endangered B2a+ b(ii,iii,iv,v) Version 3.1**

Assessment information

- Extent of occurrence is more than 100Km^2. Population identified in more than 15 localities in Kerala, Tamil Nadu, Karnataka in a stretch of about 110Km.
- Area of occupancy estimated to be less than 10 km2, severely fragmented, population declining, majority of mature individuals scored outside protected habitats, hab tats declininng. B2a+ b(ii,iii,iv,v)
- Population size more than 250 mature individuals.

Conclusion: *Vanda thwaitesii* meet the criteria B2a+ b(ii,iii,iv,v) to consider under Critically Endangered Criteria.

3.2.2.7 Conservation action: Seed culture and restoration

3.2.2.7.1 Methodology

Capsules: Capsules of *Vanda thwaitesii* (Fig. 23a) collected after 8-10 months of flowering may be used to raise seedlings. As the seedlings were raised for restoration, fully mature capsules with reddish brown seeds (Fig 23b) are preferred and thus 8-10 months old capsules were used. Seeds from 4 distinct populations in Idukki WLS, Gavi, Wayanadu, and Coorg districts in Kerala and Karnataka were subjected to culture initiation and multiplication. Generally, more than 90% of the seeds extracted from mature capsules possess fully formed embryos.

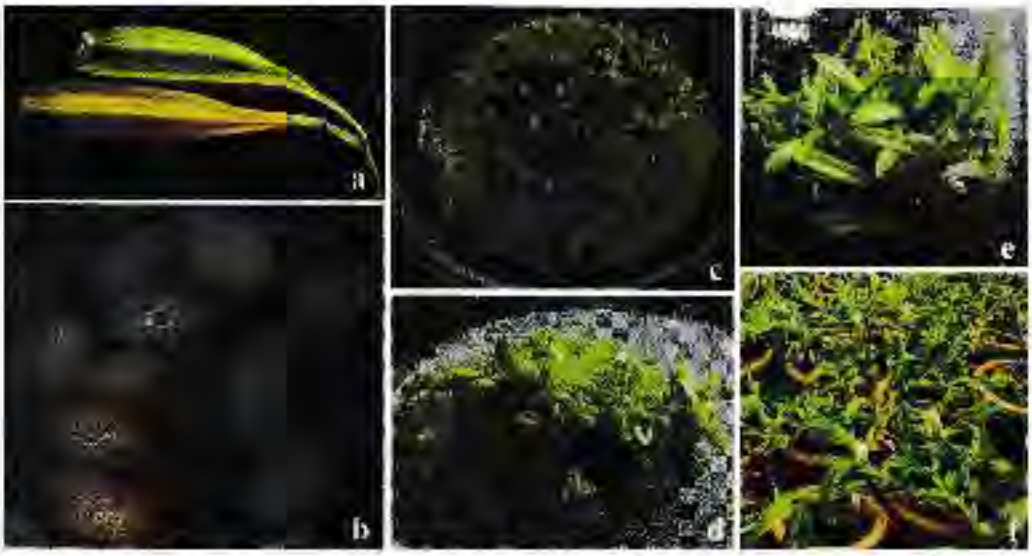

Fig 23. *V. thwaitesii* seed culture. a. Mature capsule, b. Seeds, c. Protocorms obtained after 90 days of culture in Mitra *et al* liquid medium + 0.02% CH, d. Seeds cultured on agar gelled NDM medium +0.02% CH showing protocorm development and seedling differentiation, e. Differentiated seedlings cultured on NDM + 5% banana pulp showing vigorous growth, f. Seedlings established in the nursery.

Media: Mitra *et al.* (1976) medium supplemented with CH (0.02-0.05%) is ideal to get more than 90% germination and development into yellowish green or green protocorms in 60days. Seeds sowing in agar gelled (0.6%) Mitra or NDM supplemented with 0.02% CH is also ideal for germination, early differentiation and vigorous growth of protocorms (Fig 23d)

Surface sterilization and inoculation: Wash the capsules (collected before dehiscence) thoroughly in running tap water using labolene. Wipe the capsules in spirit, dip in spirit, flame for 2-3 sec three times and place in a sterile petriplate. Cut open the capsules under a laminar airflow and transfer about 600 seeds into 250 ml conical flasks containing about 60 ml pre-sterilized liquid media (10 seeds/ml). Examine a sample of seeds under microscope to confirm the presence of viable seeds (seeds possessing fully formed embryos (Fig. 23b) Small density of seeds only favored vigorous growth of protocorms (Fig 23c).

Culture: Incubate the cultures in a culture room illuminated with cool fluorescent tubes 16hr and swirling of the flasks manually once in a day. Germination may be assessed at 15 day intervals. Seed germination is visible after about 15 days of inoculation as evidenced from the swelling of seeds and growth into protocorms (Fig. 23c). An average 85% (upto) of the seeds may be germinated even though 95% of the seeds possess fully formed embryos.

Subculture: Subculture the protocorms obtained after 90 days of culture initially in agar gelled (0.6%) Mitra *et al* medium supplemented with 0.05% CH. Differentiated protocorms after development of shoot and root initials (Fig 23d), upon subculture into New Dogashima medium (NDM, Tokuhara and Mii 1993) without cysteine but fortified with 5% banana pulp give vigorous seedlings (Fig. 23e). They develop into shoots with 3-4 leaves and 3-5 roots in 12 months period when they are ready for *ex vitro* hardening and transfer into nursery (Fig 23e).

Nursery establishment: De-flasked seedlings transferred to a mist house (misting lasting for 30s at 1-3 h intervals depending on season) in a potting mixture of charcoal granules and tile pieces (1:1) is ideal for hardening and nursery establishment. The seedlings were allowed to grow themselves, as in the natural habitat without any external application of chemical fertilizers. But, bark powder prepared out of shavings from natural hosts as *Dalbergia latifolia* and *Careya arborea* were mixed with the potting mixture during repotting. For restoration, seedlings co-cultured with symbiotic fungus or reared in potting mixture containing fungus inoculum were used. Seedlings reared in the nursery

for 1-2 years (Fig 23f) were ready for restoration work at the time of starting of current project.

Confirmation of symbiotic fungi in seedlings used for restoration: Root segments from seedlings of *V. thwaitesii* reared in the nursery in presence symbiotic fungus VT3 was inoculated in fungal isolation medium to confirm the growth of the fungus. Besides, TS of the roots was also observed under the microscope to confirm the presence of mycorrhizal colonization in the cortical region.

Restoration: Seedlings were first tied on the bark of *Terminalia paniculata* and reared for one year at JNTBGRI. The seedlings thus reared were tied using polypropylene threads on trunks of native host trees as *Dalbergia latifolia, Mangifera indica, Cinnamomum verum, Gmelina arborea, Persea macrantha* and *Careya arborea* in Kzhukkanam forest section of Idukki WLS and Padinjarethara forest section of South Wayanadu Forest Division, two native localities of *V. thwaitesii*. A few plants of *V. thwaitesii* could be identified in these localities and thus mixture of seedlings from different populations was planted as part of reinforcement procedure. Seedlings from different populations planted at JNTBGRI campus (conservation introduction) and Thirunelli in Wayanadu (Reinforcement) as part of an already concluded project supported by DBT Government of India was also monitored as part of the present project.

3.2.2.7.2 Achievements

3.2.2.7.2.1 Confirmation of Symbiotic association

One strain 'VT3' (Fig 24a) proved earlier having symbiotic activity was re-isolated from symbiotic seedlings (Fig 24b,c) roots. TS of roots showed active mycorrhizal colonization (Fig 25).

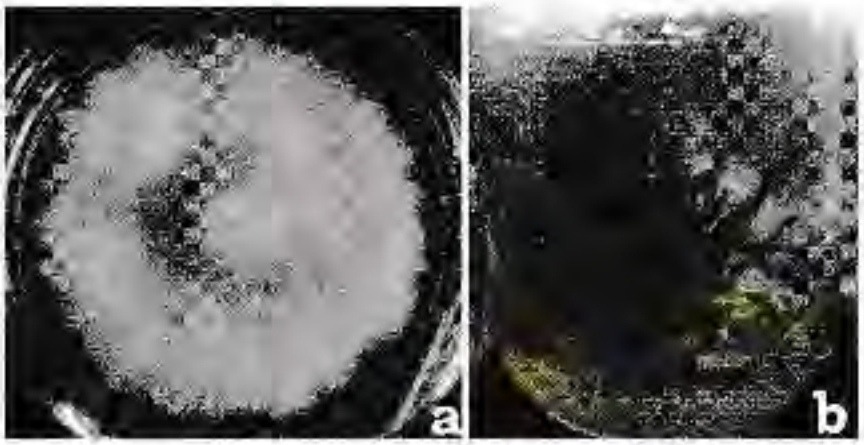

Fig 24a. Symbiotic fungus VT3 from the seedling roots of *V. thwaitesii*. b. Symbiotically produced seedling using the fungus VT3.

Fig 24c. Symbiotically produced seedlings of *V. thwaitesii* in the nursery

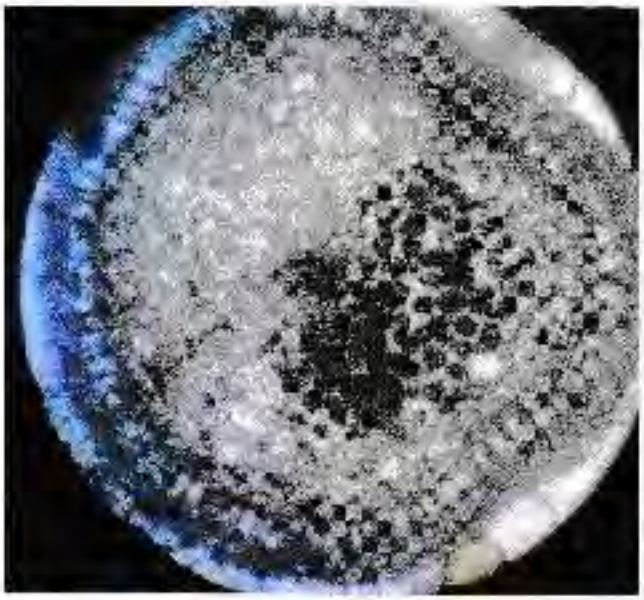

Fig 25. TS of seedling root of *V. thwaitesii* showing active mycorrhizal colonization in the cortex

3.2.2.7.2.2 Preparation for restoration

Seedlings of *V. thwaitesii* in two categories were used for restoration. The first category includes the seedlings raised asymbiotically, reared in the nursery in presence of symbiotic fungus (Fig 26a) and tied on the bark of dried *T. paniculata* bark (Fig 26b). They were reared in open field condition at JNTBGRI condition for one year (Fig 27) before taken for restoration. The second category seedlings are those symbiotically produced under *in vitro* conditions and reared in the nursery for 3 years (Fig 28a), separated from potting mixture (Fig 28b), packed in wet newspaper and transported to the restoration localities in Idukki and Wayanadu.

Fig 26a. Seedlings of *V. thwaitesii* reared with symbiotic association. b. The seedlings tied on bark as a preparative step prior to restoration

Fig 27. Seedlings of *V. thwaitesii* tied on bark and reared in open field condition at JNTBGRI prior to be taken for restoration

Fig 28a. Symbiotically raised seedlings reared in the nursery for three years, b. Seedlings detached from potting medium and taken for restoration

3.2.2.7.2.3 Restoration

As per IUCN Guidelines reintroduction, reinforcement, and conservation translocation/ introduction are recommended for saving an endangered species from extinction. Reintroduction is the process of propagating a species outside their native habitat and introducing into their native habit where the species was available but latter vanished due to several reasons. They are restocked from gene bank material or *ex situ* conservatories. As far as *V. thwaitesii* is concerned, isolated populations are still available in inhabited land and disturbed forests in addition to protected forests in Idukki Wildlife Sanctuary and Wayanadu Forest Division. Therefore, fruits have been collected from different populations mainly focusing on disturbed forests and inhabitant lands. Seedlings were produced and planted into their native localities where small population (Fig 29) is still available, to enhance their genetic base (diversity) which is essential for their adaptability over changing environmental conditions. This entire process is referred as reinforcement. As an alternative method, to conserve them *ex situ*, a suitable habitat outside its native locality may be considered as conservation translocation/ introduction. We tried a few seedlings at JNTBGRI forests as *C. arborea*, a natural host of *V. thwaitesii* is abundant in the campus and adults introduced and planted on their trunks acclimatized and exhibited luxuriant growth (Fig 30) over 5year period.

Fig 29. Isolated native populations of *Vanda thwaitesii* still surviving at Kuttiyamvayal, Wyanadu (a,b) and Idukki Wildlife Sanctuary (c,d)

Fig 30. *Vanda thwatesii* (adults) introduced at JNTBGRI campus and planted on *Careya arborea* a natural host, showing luxurient growth after 7years of introduction.

3.2.2.7.2.3.1 Previous restoration trials

Reinforcement

Seedlings of *V. thwaitesii* planted as part of a previous project during 2014-15 was monitored, in addition to the planting of new seedlings in Wayanad and Idukki WLS. More than 25% of the seedlings planted in Idukki WLS (28.9) and Thirunelli (26.2) were still surviving (Fig 31, 32) and a total of 84 reinforced individuals are available in protected areas (Table 2). The seedlings planted on natural hosts as *Bombax ceiba* (Fig 31 a, b), *Careya arborea* (Fig 31c), *Pterocarpus marsupium* (Fig 31d), adapted to the natural environment of Wayanadu habitat with new growth of leaves and roots after 3 years of planting. In natural habitat of Idukki WLS, *Gmelina albovea, Cinnamomum veerum*, and *Artocarpus integrifolius* were used as hosts and the survived plants (28.9%) showed satisfactory growth with luxurient root system (Fig 32) when observe after 5 years. However, those seedlings planted on *Syzygium cumini* which is not a natural host, showed poor growth (Fig 32) as the root system was not luxurient.

Fig. 31. *V. thwaitesii* reinforced at Wayanadu after 4 years. a. on *Bombax ceiba* immediately after planting, b. the latter plants after 4 years, c. on *Careya arborea*, d. on *Pterocarpus marsupium*

Fig 32. *V. thwaitesii* reinforced at Idukki Wildlife Sanctuary after 5 years. a. on *Gmelina arborea*, b. on *Cinnamomum verum*, c. on *Artocarpus integrifolius*, d. on *Syzygium cumini*

Conservation introduction

In addition to the reinforcement trials into the native localities, an attempt of conservation introduction at JNTBGRI campus (180m altitude) was made by planting on native hosts as *Careya arborea* and *Tectona grandis*. Out of 296 seedlings planted at JNTBGRI campus, 135

survived the extreme dry condition in 2019 but only 104 numbers left with 35% survival when observed in June 2020 (Table 4; Fig 33). This is satisfactory for such a species otherwise adapted to cold conditions of altitudes above 600m. However, the growth was very slow and poor especially those planted on *T. grandis* (Fig 33a) to consider the climatic condition at JNTBGRI conducive to *V. thwaitesii*. Nevertheless, the seedlings planted in pots and reared under cultivated conditions providing bark powder only as the source of nutrients and watered once daily during dry climatic conditions showed luxuriant growth (Fig 34)

Table 4. Restoration of *Vanda thwaitesii* at Wayanadu and Idukki WLS as part of a concluded project

Year of restoration	Locality	No. of seedling tried	No. of seedlings Survived; 1-2Yr	% Survival After 1-2 year	% Survival After 4-5 years in 2019-20
2015	Idukki WLS	121	62	51.2	28.9 (35)
	Thirunelli	187	144	77.0	26.2 (49)
	JNTBGRI	296	250	84.4	35.1 (104)
	Total	616	456	74.0	

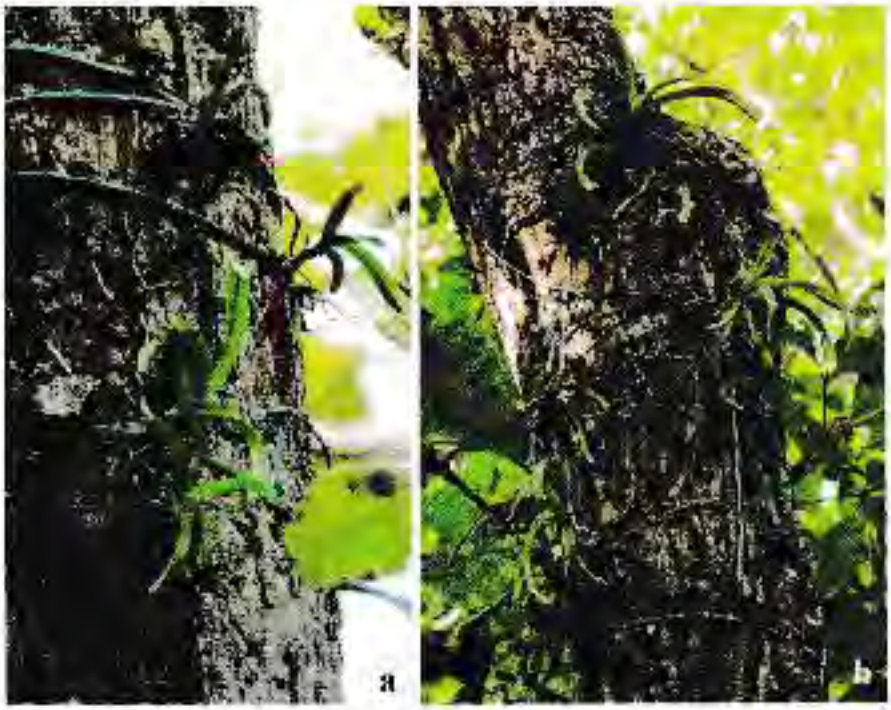

Fig 33. Seedlings *of V. thwaitesii* planted on hosts as (a) *Tectona grandis* and (b) *Careya arborea* at JNTBGRI campus as part of conservation introduction, after 5 years

Fig 34. Seedlings of *V. thwaitesii* grown under controlled conditions at JNTBGRI, after 7 years of transfer to the field

3.2.2.7.2.3.2 Reinforcement during 2018-19

In 2018, a total of 692 seedlings previously hardened on bark (Fig 27) were reinforced at Idukki WLS and Kuttiyamvayal in Wayanadu (Fig 35) by tying on the tree trunks using polypropylene thread. In the initial trials, a few plants were also tied using jute and coir but such fiber material disintegrated before the establishment of the seedlings and thus not tried in the later trials. They showed 79.9 and 68.4% survival respectively and thus 338 and 184 individuals survived after two years (Table 5-7, Fig 35). One of the seedlings flowered and exhibited natural fruit set (Fig 35d). The natural host plants as *Gmelina arborea, Dalbergia latifolia, Mangifera indica, Careya arborea, Cinnamomum verum* and *Persea macrantha* were used as hosts (Table 4, 5) showing best survival and establishment on natural hosts as *C.*

Fig 35. Seedlings of *V. thwaitesii* previously planted on bark and reared under open field conditions at JNTBGRI planted on host plants in Kuttiyamvayal forests in Wayanad. a. immediately after planting, b. after one year of planting.

arborea, *C. veerum* and *Persea macrantha*. But, in an isolated trial, none of the seedlings planted on *Dillenia indica* survived probably due to fire happened under the tree. In addition, 172 seedlings were directly tied onto trunks of natural host as *Careya arborea* both in Kuttiyamvayal and Idukki Wildlife sanctuary with more than 95% survival (Table 8, Fig. 36).

Fig 35c,d. Seedlings of *V. thwaitesii* previously planted on bark and reared under open field conditions at JNTBGRI planted on host plants in Kuttiyamvayal forests in Wayanad after two year of planting; one plant flowered and showed natural fruit set (d).

Table 5. Restoration of *Vanda thwaitesii* at Wayanadu and Idukki WLS

Locality	Year	No. of seedling tried	Hardened(H)/ Direct(D)	No. of seedlings Survived: 1-2Yr	% Survival After 1-2 year
Kuttiyamvayal, Wayanadu	2018	423	H	338	79.9
	2019	56	D	Not observed	>90%
Idukki WLS, Idukki	2018	269	H	184	68.4
	2019	116	D	111	95.7
Total		864		633+	82.9

Table 6. Details of restoration at Kottathavalam of Idukki Wildlife Sanctuary on 27-11-2018. Seedlings planted on *V. paniculata* bark and reared for 1 year was used for restoration

No.	Name of host	No of seedlings planted on 27-11-2018	No of seedlings survived as on 19-02-2020	% survival
1	*Careya arborea*	82	68	82.93
2	*Dalbergia latifolia*	16	04	25.00
3	*Cinnamomum veerum*	44	35	79.54
4	*Oroxylum indicum*	05	02	40.00
5	*Dillenia indica*	06	00	0.00
6	*Gmelina arborea*	43	22	51.16
7	*Persea macrantha*	73	53	72.60
Total		269	184	68.4

Table 7. Details of restoration at Kuttiyamvayal, Padinjarethara Forest section of South Wayanad Forest Division. Seedlings planted on *T. paniculata* bark and reared for 1 year was used for restoration.

No.	Name of host	No of seedlings planted on 27-04-2018	No of seedlings survived as on 01-05-2019	% survival
1	*Careya arborea*	315	247	78.4
2	*Dalbergia latifolia*	48	32	66.7
3	*Mangifera indica*	18	13	72.2
	Memecylon edule	22	19	86.4
	Pterocarpus marsupium	29	27	93.1
Total		432	338	78.2

Table 8. Restoration of symbiotic seedlings in Idukki WLS and Wayanad. The seedlings reared in the nursery for 2 years, uprooted and planted directly on tree trunks

No.	Name of host	No of seedlings planted on 22-05-2019	No of seedlings survived as on 20-02-2020	% survival
		Idukki WLS		
1	*Careya arborea*	96	95	98.9
2	*Gmelina arborea*	20	16	80.0
		Kuttiyamvayal, Padinjarethara, Wayanadu		
3	*Careya arborea*	56	ND	-
Total		172	111+	

ND- Not observed

Fig 36a,c Reinforcement through direct tying of symbiotic seedlings on trunks of *Careya arborea* in Idukki WLS immediately after planting.

Fig 36b,d. Reinforcement through direct tying of symbiotic seedlings on trunks of *Careya arborea* in Idukki WLS after one year after planting.

3.2.2.8 Conclusions

Even though this species is notified by Government of India as endangered, Conservation monitoring centre, IUCN did not evaluate its status. However, based on field studies as part of the present study and already concluded project, we generated population data and evaluated present status based on IUCN guidelines Version 3.1. Due to severe fragmentation, loss of habitats and very poor heterogeneity, possible spread of the species is very less. Also the existing populations are outside protected forests. Thus we concluded that the species may be placed under **critically endangered category**. Our restoration efforts of planting 308 seedlings (1yer-old) during 2015 is only partially successful, as only 84 of them in Wyandu and Idukki WLS survived after 5 years. However, the planting of 2-3 year old seedlings (864) during 2018-19 both in Wayanad and Idukki WLS showed about 85% establishment. The seedlings were produced through culture of seeds collected from different populations and thus it is expected that genetic diversity from different populations will establish at Wayanad and Idukki WLS where small numbers of natural plants are still surviving. The factors as symbiotic fungus and pollinators are present in those localities as natural fruit set and seedlings recruitment observed. Nevertheless, we incorporated compatible symbiotic fungus in the seedlings used for restoration. More than 600 restored seedlings are expected to be established at both the localities for effective conservation of the species as an initial step in the conservation of *V. thwaitesii*.

3.2.3 *Vanda wightii* Rch.f.

3.2.3.1 Description

Vanda wightii Rch.f. reported from India and Sri-Lanka is one among the 40 species of *Vandas* distributed in the Indo-Malayan region (Limansela *et al.*, 2002). It is originally described by Reichenbach.f (1864) based on Robert Wight's collection from Vaulyar and Palghatcherry (1849) and Thwaite's collection from Sri Lanka (Satheeshkumar *et al.*, 2006). It is supposed to be extinct as it has not been re-sighted in the wild ever since Wight's collection (Limansela *et al.*, 2002). Later during 2000-02 periods, the species is re-collected from Belthangady and Subramanya in Dakshina Kannada district of Karnataka; Nidiyanga in Kannur and Melattur near Palakkad district of Kerala (Satheeshkumar *et al.*, 2006). The species is described as distributed in narrow pockets with restricted numbers and later under section 38 of the Biological Diversity Act 2002, the Central Government notified that *V. wightii* is on the verge of extinction and prohibited/regulated collection along with other 25 plant species from Western Ghats (MOEF, 2009). The ministry also called for studies on all aspects of the notified species for holistic understanding and propagation of the species for the purpose of *in situ* and *ex situ* conservation and rehabilitation.

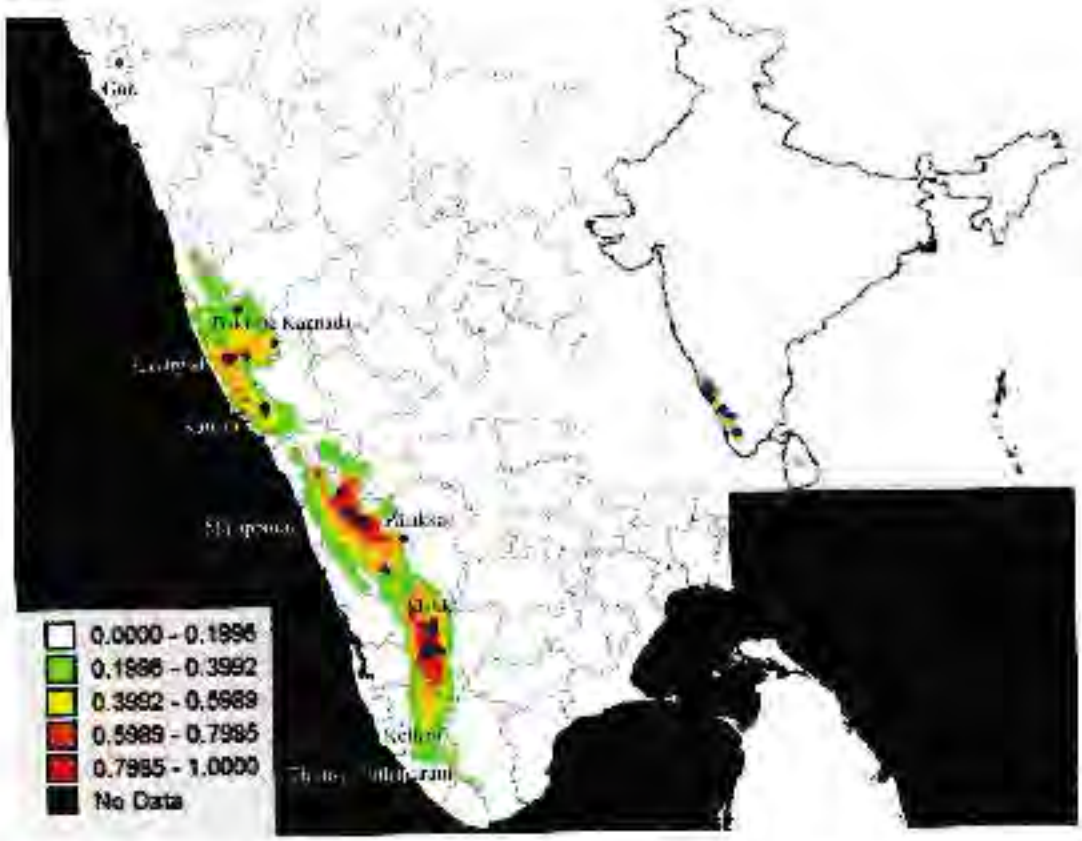

Fig 37. Distribution of *Vanda wightii* (Blue spots) overlaid on a distribution model generated using maxent modeling software.

3.2.3.2 Distribution

It is an epiphytic orchid which is endemic to the Western Ghats in the states of Kerala, Tamil Nadu and Karnataka at 70-870m altitudes in tropical dry deciduous forests (Table 9). In addition, later studies confirmed its presence in Goa and Idukki as well as Kasargod districts of Kerala. Our studies as part of a concluded project (JNTBGRI, 2016) revealed its potential habitats extending from Idukki district of Kerala to Udupi districts of Karnataka (Fig. 37). Even though the species is reported from Goa also, which provide 0-19% probable habitat while there is a tendency to shift the suitable habitat towards south (Fig 37). More than 53% of the occurrence points fall in the red region in Idukki, Palakkad and Malappuram Districts of Kerala supporting most ideal climatic condition for *V. wightii* (Table 10). Nevertheless, richest population identified in Kasargod falls under orange region indicating a climatic deviation that may lead to future population decline in this region. Significant population of the species has been reported in Karadka forest section of Kasargod Forest division, Idukki WLS and Ponmudi dam area of Idukki forest division but high floral diversity (Fig. 38) also existed in inhabitant region in Kannur, Kasargod and Palakkad districts.

Table 9. Distribution of *V. wightii* as per cited literature and our previousstudies

Sl. No.	Locality	State/Country	Citation/ collection	Reference
1	Vaulyar– Walayar	Kerala, India	1849	Sathishkumar *et al* 2006
2	Palghatcherry=Palakkad	Kerala, India	1849	
3	Ceylon	Sri Lanka	Prior to 1864	
4	Coimbatore	Tamil Nadu, India	1849	
5	Nidiyanga, Kannur	Kerala, India	2001,2002	
6	Belthangady	Karnataka, India	2003	
7	Subramanya	Karnataka, India	2000	
8	Melattur, Malappuram	Kerala, India	2006	
9	Mangalapuram	Karnataka, India	2006	
10	Karadka, Kasargod	Kerala	2016	JNTBGRI 2016
11	Idukki WLS	Kerala	2016	
12	Ponmudi dam, Idukki	Kerala	2016	
13	Kottoppadam, Palakkad	Kerala	2016	
14	Vadapuram, Malappuram	Kerala	2016	
15	Goa	Goa	2016	Jalal and Jayanthi 2016

Table 10. Distribution of occurrence points in probable area

Probability class	Number of Occurrence points	% of total Occurrence points	Dominant locations
0.00-0.19	1	0.59	Goa
0.20-0.39	3	1.80	Palakkad Gap, Dakhina Kannada
0.40-0.59	8	4.72	Kannur, Dakhina Kannada
0.60-0.79	69	40.82	Kasargod
0.80-1.00	88	52.07	Idukki, Palakkad, Malappuram, Kasargod
Total	169	100.00	

Fig 38. Floral diversity among accessions collected from inhabitant land in Palakkad and Kannur districts of Kerala.

3.2.3.3 Population information

A detailed study have been made as part of a project supported by DBT during 2010-16 period (JNTBGRI, 2016) which revealed significant number of individuals are surviving in Kasargod and Idukki districts of Kerala. The highest number of individuals of *V. wightii* was scored in Kasargod district of Kerala where the plant used to inhabit trees in forest fragments. Out of the 6002 individuals scored from Kerala and Karnataka, 3886 were in Kasargod and 961 in Idukki. Small populations could be observed in inhabitant land and road side trees in

Kannur (425), Palakkad (309), Malappuram (380) and Sulia (41). The populations in Kasargod and Idukki are mostly in protected forests. However, fruit set and seedling recruitment are negligible in all populations. Seedling recruitment was very rare. Therefore, habitat destruction and fragmentation seems to delimit spread of the species rather than genetic problems. However, the genetic diversity in the disturbed areas needs to be protected through appropriate restoration/ translocation programmes.

3.2.3.4 Habit and Habitat

V. wightii is an epiphytic orchid (Fig 2), inhabiting on *Ficus religiosa* as host at 60-80m altitudes as per the reports (Sathishkumar *et al*. 2006). Our study (JNTBGRI 2016) revealed their distribution at altitudes extending to 870m inhabiting on diverse hosts common to deciduous forests, like *Terminalia paniculata, T. elliptica, Strychnos nux-vomica, Mangifera indica, Ficus benghalensis, Tectona grandis, Dalbergia latifolia* and *Stereospermum colais*. The dominant hosts are *Strychnos nux-vomica, Tectona grandis* and *Terminalia paniculata* However, 56% of the observed individuals were on two hosts viz., *Terminalia paniculata* (1333) and *Strychnos nux-vomica* (2178) where several groups of *V. wightii* could be observed in a single tree with the number in certain group, even exceeding 30. The hosts like *Alsonia scholaris, Artocarpus heterophyllus, Dalbergia latifolia, Ficus benghalensis, Terminalia elliptica, Mangifera indica* and *Stereospermum colais* also hold appreciable numbers of *V. wightii* plants.

3.2.3.5 Decline and threat

About 80% of the total scored population as per report is in protected forests in Kasargod and Idukki. The populations in Idukki WLS and reserve forests around it accounting for 2% of total scored (less than 5% of total suitable area surveyed) are safe and do not require any conservation measures. The diversity in other localities in Kannur, Malappuram, Palakkad and Idukki districts were observed on road side trees, inhabited land and Teak plantations under Forest Department that are highly vulnerable to genetic loss. Their population with appreciable floral diversity is not safe in the native localities. The dominant populations in Kasargod are distributed in forest fragments surrounded by inhabitant land. Besides, the population is in small forest patches around laterite rocky exposures and thus will be victim of reduced rain and consequent drought due to climatic change. The species growing on evergreen trees as *Strychnos nux-vomica* may survive but those on deciduous trees as *Terminalia paniculata* may struggle as experienced during our surveys. Fruit set and seedling recruitment are very much reduced. This factor coupled with habit destruction/fragmentation

causes further population decline and spread of the species. Propagation of the species from diversity in the risky habitat and reinforcement into safe localities are thus essential to conserve the entire genetic diversity of *Vandaighii*.

3.2.3.6 Assessment of status as per IUCN Guidelines (Annexure-I)

Vanda wightii meet the criteria B1a+b(ii,iii,iv); B2a b(ii,iii,iv) to consider as **Endangered**

Assessment information

Present Population status
Total sampled area: 62,000sqm

Total distributed area: 11,979,8915qm=1.9SqKm.

Total mature plants seened in sanctuaries and reserve forests 4847appx

Total mature plants seened in inhabitant land=1155

Total projected population in protected forests/teak plantations= More than 10,000

Extent of distribution=108 KM stretch 2,750SqKm excluding Goa

Population trend: Decreasing in inhabited area; increasing in protected habitats

- Extent of occurrence estimated is less than 5000 km^2. Severely fragmented except at Idukki WLS. Continuing decline in inhabitant land. Area of occupancy less than 500Km^2. **B1a+b(ii,iii,iv); B2a+b(ii,iii,iv)**
- Population size estimated to more than 2,500 mature individuals. Population decline occurred in the past due to habitat destruction
- Population size estimated more than 250 mature individuals. More than 6,000 observed.
- Quantitative analysis is not undertaken, but there is no possibility of extinction as self-perpetuating population already established in a more suitable and protected habitat at Idukki WLS and adjoining protected forests.

Conclusion: *Vanda wightii* meet the criteria B1a b(ii,iii,iv); B2a+b(ii,iii,iv) to consider as Endangered

Decision: Endangered B1a+b(ii,iii,iv); B2a+b(ii,iii,iv) version 3.1

3.2.3.6 Conservation action: seed culture and reinforcement

3.2.3.6.1 Methodology

Capsules: Capsules of *Vanda wightii* (Fig. 39a) collected after 10-14 months may be used to raise seedlings. As the seedlings were raised for restoration, fully mature capsules with reddish brown seeds (Fig 39b) are preferred and thus 12-14 months old capsules were used. Seeds from 6 distinct populations in Idukki, Palakkad, Malappuram, Kannur and Kasaragod districts of Kerala

were subjected to culture initiation and multiplication. Generally, more than 80% of the seeds extracted from mature capsules possess fully formed embryos.

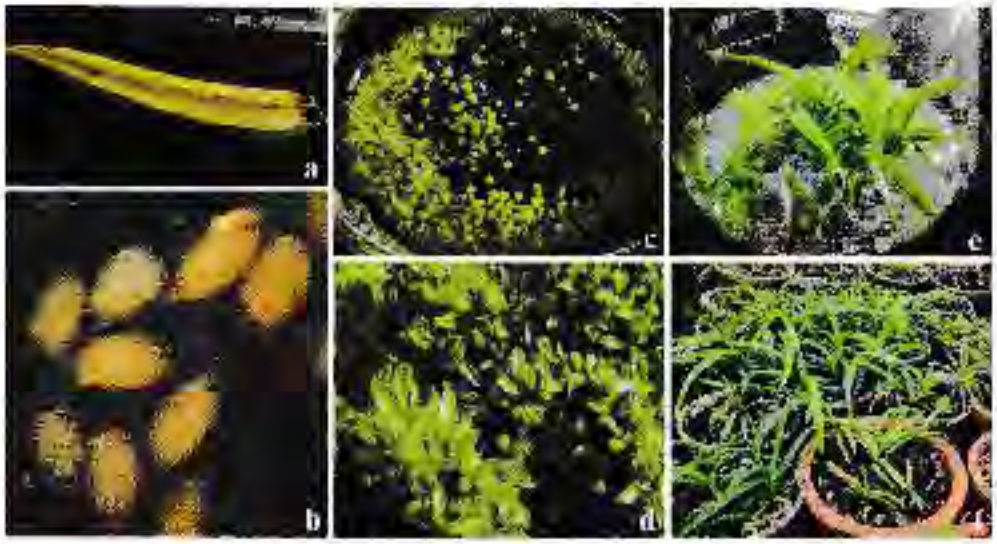

Fig 39. Seed culture and seedling production in Vanda wightii. a. Mature capsule, b. Seeds, c. 90 day-old protocorms developed in Mitra et al+ 0.02%CH liquid medium, d. Early differentiation and formation of seedlings on seed culture in agar-gelled NDM +0.02% CH after 120 days, e. Vigorous growth of seedlings observed in NDM 5% banana pulp medium. f. Seedlings established in the nursery, after 3 years.

Media: Mitra *et al.* (1976) medium supplemented with Coconut water (10%) or CH (0.02%) is ideal to get more than 90% germination and development into yellowish green or green protocorms in 60days.

Surface sterilization and inoculation: Wash the capsules (collected before dehiscence) thoroughly in running tap water using labolene. Wipe the capsules in spirit, dip in spirit, flame for 2-3 sec three times and place in a sterile petriplate. Cut open the capsules under a laminar airflow and transfer about 600 seeds into 250 ml conical flasks containing about 60 ml pre-sterilized liquid media (10 seeds/ml). Examine a sample of seeds under microscope to confirm the presence of viable seeds (seeds possessing fully formed embryos, Fig. 39b). If the inoculated seed density is high, the protocorms ceased to grow after germination and early development.

Culture: Incubate the cultures in a culture room illuminated with cool fluorescent tubes room and swirling of the flasks manually once in a day. Germination may be assessed at 15 day intervals. Seed germination is visible after about 15 days of inoculation as evidenced from the swelling of seeds and growth into protocorms (Fig. 39c). An average 90% (appx) of the seeds may be germinated even though 95% of the seeds possess fully formed embryos.

Subculture: Subculture the protocorms obtained after 90 days of culture initially in agar gelled (0.6%) Mitra *et al* medium supplemented with 0.05% CH. Differentiated protocorms after development of shoot and root initials (Fig 39d), upon subculture into New Dogashima medium (NDM, Tokuhara and Mii 1993) without cysteine but fortified with 5% banana pulp give vigorous seedlings (Fig. 39e). They develop into shoots with 3-4 leaves and 3-5 roots in 12 months period when they are ready for *ex vitro* hardening and transfer into nursery (Fig 39e).

Nursery establishment: De-flasked seedlings transferred to a mist house (misting lasting for 30s at 1-3h intervals depending on season) in a potting mixture of charcoal granules and tile pieces (1:1) is ideal for hardening and nursery establishment. The seedlings were allowed to grow themselves, as in the natural habitat without any external application of chemical fertilizers. But, bark powder prepared out of shavings from natural hosts as *Dalbergia latifolia, Tectona grandis, Terminalia paniculata, Careya arborea* were mixed with the potting mixture during repotting. For restoration, seedlings co-cultured with symbiotic fungus or reared in potting mixture containing fungus inoculum were used. Seedlings reared in the nursery for 1-2 years (Fig 39f) were ready for restoration work at the time of starting of current project.

Confirmation of Mycorrhizal association: The seedlings of *V. wightii* were reared in the nursery in presence of a symbiotic fungus 'VT3', a ceratobasideaceae clone isolated from *V. thwaitesii*. TS of seedling roots were observed under the microscope to confirm mycorrhizal colonization.

Restoration: Seedlings were first tied on the bark of *Terminalia paniculata* and reared for one year at JNTBGRI. The seedlings thus reared were planted on trunks of native host trees as *Tectona grandis, Terminalia paniculata* and *Careya arborea* in Kzhukkanam forest section of Idukki WLS, one of *V. wightii*'s native locality. Significant numbers of *V. wightii* are still present in this sanctuary and thus mixture of seedlings from different populations was planted as part of reinforcement procedure. Seedlings from different populations planted at JNTBGRI campus (conservation introduction) as part of an already concluded project supported by DBT Government of India, was also monitored regularly.

3.2.3.6.2 Achievements

Significant populations of *V. wightii* left in Palakkad, Malappuram and Kannur districts in Kerala are in inhabited land. It is also distributed in protected forests in Idukki Wildlife Sanctuary and reserve forests in Idukki and Kasargod districts of Kerala. Therefore, fruits

have been collected from different populations mainly focusing on inhabitant lands. Seedlings were produced and planted into their native localities where small population (Fig. 40a) is still present, to enhance their genetic base (diversity) which is essential for their adaptability over changing environmental conditions. As an alternative method, to conserve them *ex situ*, a suitable habitat outside its native locality may be considered as conservation translocation/ introduction. We tried a few seedlings at JNTBGRI forests as *T. paniculata, D latifolia* and *T. gemdis* a few natural hosts of *V. wightii* are present in the campus and adults introduced and planted on their trunks acclimatized and exhibited luxuriant growth (Fig. 40b) over 5year period.

Fig. 40a. Native population of *Vanda wightii* observed in Idukki WLS. b. Adult plant introduced at JNTBGRI campus, acclimatized and flowered after 3 years.

3.2.3.6.2.1 Preparation for restoration

Seedlings of *V. wightii* from different populations produced both symbiotically and asymbiotically were tied on dried bark of *T. paniculata* (Fig 41a) and reared at JNTBGRI in open field condition for 1-2 years (Fig 41b). The seedlings thus reared were transported to Keezhukkanam of Idukki WLS in May and November 2018.

Fig 41a. Seedlings of *Vanda wightii* tied on dried bark of *Terminalia paniculata* as a preparative step for restoration, b. The latter plants reared in open field conditions.

3.2.3.6.2 Restoration

Previous restoration trials

Reinforcement:

Seedlings of *V. wightii* planted as part of a previous project during 2014-15 was monitored, in addition to the planting of new seedlings in Idukki WLS. Only less than 25% of the seedlings planted in Idukki WLS were surviving (Fig 42) with new roots and satisfactory growth. Many of the seedlings were found dropped due to disintegration of jute thread, before proper establishment of the seedlings. Only the natural hosts as *Terminalia paniculata* and *Tectona grandis* selected for restoration and supported satisfactory growth (Fig 42).

Conservation introduction: In addition to the reinforcement trials into the native localities, an attempt of conservation introduction at JNTBGRI campus (180m altitude) was made by planting on native hosts as *Terminalia paniculata*, *Tectona grandis* and *Dalbergia latifolia*. Out of 319 seedlings planted at JNTBGRI campus in 2015, 201 (63%) survived the extreme dry condition in 2019 and dry weather in 2020 (Table 11; Fig 43). This is satisfactory for such a species otherwise adapted to cold conditions of altitudes above 600m. *V. wightii* showed better growth on host as *T. paniculata* and *Dalbergia latifolia* compared to *T. grandis* used as host (Table 11, Fig 43).

Fig 42a-b. Reinforced seedlings of *V. wightii* at Idukki WLS after 5 years

Fig 42c-d. Reinforced seedlings of *V. wightii* at Idukki WLS after 5 years

Table 11. Restoration of *Vanda wightii* at Idukki WLS and JNTBGRI Campus in previous trials

Year	Locality	No. of seedlings tried (2015)	No. of seedlings Survived (2016)	% survival after 1-2 year	% survival after 4-5 yeas (2019-20)
2015	Anchuruli	158	137	86.7	ND
	Idukki WLS	244	174	73.1	
	JNTBGRI campus	319	299	93.7	63.0 (201)
Host preference at JNTBGRI campus					
Host					
Terminalia paniculata		167			74.8 (125)
Tectona grandis		107			51.4 (55)
Dalbergia latifolia		20			85.0 (17)
Careya arborea		10			0.0 (0)
Alstonia scholaris		15			26.7 (4)
Total		319	299	93.7	63.0 (201)

Reinforcement during 2018-19

In 2018-2029, a total of 357 seedlings previously hardened on bark were reinforced at Keezhukkanam of Idukki WLS by tying on the tree trunks using polypropylene thread. In the initial trials, a few plants were also tied using jute and coir but such material disintegrated before the establishment of the seedlings and thus not tried in the later trials. They showed 42.6% survival and thus 156 individuals survived after two years (Table 12, Fig 44). The

natural host plants as *Dalbergia latifolia*, *Careya arborea*, and *Terminalia paniculata* supported better growth compared to *Tectona grandis* (Table 12).

Fig 43. Conservation introduction of *V. wightii* at INTBGRI campus. 2-3 year old seedlings planted on *Terminalia paniculata* (a, b), *Tectona grandis* (c) and Dalbergia latifolia (d), after 5 years

Table 12. Restoration of *Vanda wightii* at Idukki WLS in 2018 and 2019

Host	No. of seedlings tried 29/5/18 and 28/11/18	No. of seedlings Survived	% survival after 1-2 year (19-02-2020)
Terminalia paniculata	155	71	45.8
Tectona grandis	80	12	15.0
Careya arborea	64	40	62.5
Dalbergia latifolia	43	27	62.7
Pterocarpus marsupium	15	2	13.3 8
Total	357	152	42.6

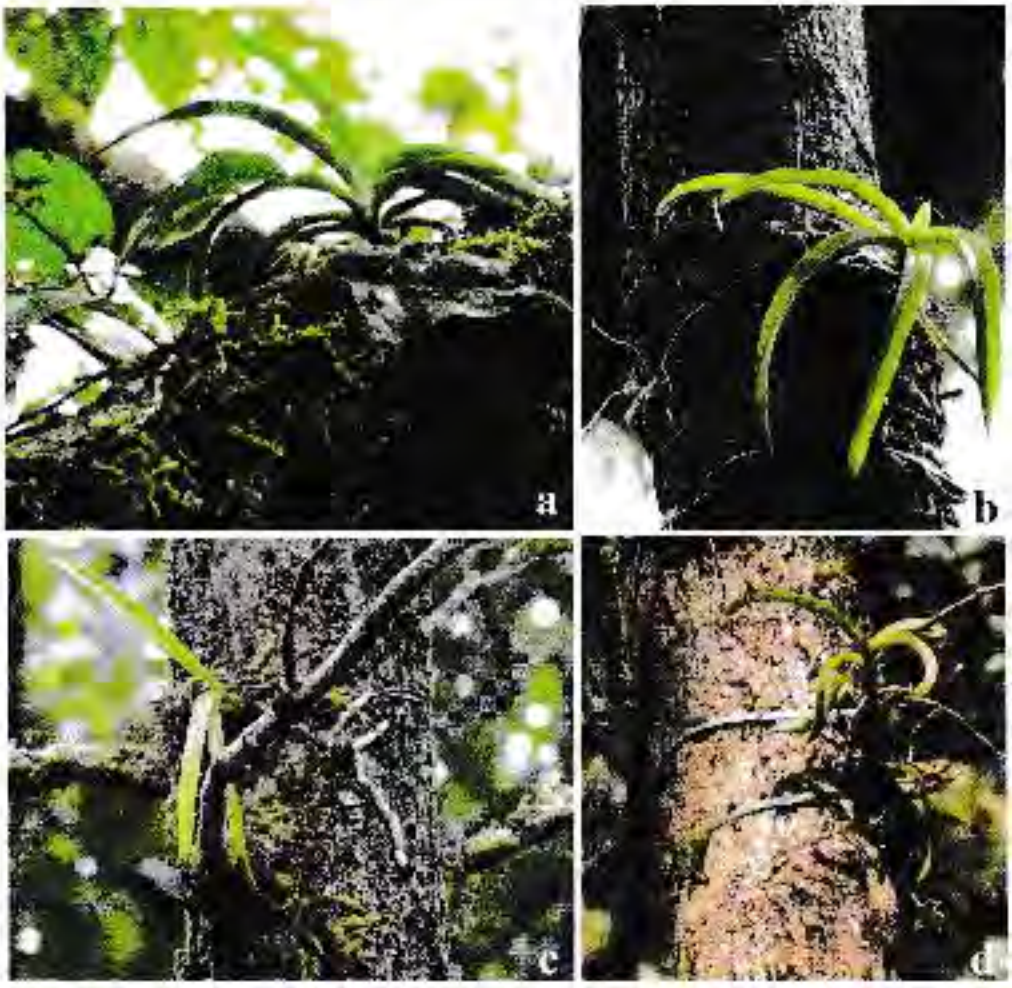

Fig 44a-d. Seedlings of *V. wightii* reinforced at Idukki WLS in May 2018, after Two years

3.2.3.7 Conclusions

Even though this species is notified by Government of India as endangered, Conservation monitoring centre, IUCN did not evaluate its status. However, based on field studies as part of the present study and already concluded project, we generated population data and

evaluated present status based on IUCN guidelines Version 3.1. Due to habitat fragmentation, loss of habitat, significant population decline, poor regeneration status and possible shift of ideal habitat towards south, we recommend to place the species under endangered category. Even though large population could be identified in Kasargod District, the plants seem to propagate through vegetative method rather than through seedling recruitment. Severe fragmentation and environmental stress also may affect the decline of the species in that area. However, the plant seems to be adapted more in Idukki District. The plant distribution model also demonstrated extension of suitable area towards Western Ghats region in Kollam and Thiruvnanthapuram. It is substantiated by the better establishment of *V. wightii* seedlings at JNTBGRI campus situated at north extreme of Thiruvananthapuram District. Out of 319 seedlings planted, 201 established at JNTBGI after 5 years with luxuriant growth. This location also holds conducive environment for seedling recruitment and fruit set, as other vandaceous orchids are also present at JNTBGRI campus as native plants. Thus, *V. wightii* can establish a self perpetuating population at JNTBGRI forests. The restoration made at Idukki WLS was not satisfactory as only 142 out of 357 survived after 1-2 years which is not sufficient to establish the entire genetic diversity of the species.

Large populations of *V. wightii* present in teak plantations around Ponmudi dam, Idukki reservoir etc. All the plantations belong to Kerala State Forest Department. Rehabilitation of the orchids in those plantations into protected forests is essential to conserve the entire diversity in that area if the teak trees are removed as part of forest practices. Restoration of more diversity from inhabited areas needs to be continued in more locations Eg: near ponpara, a buffer zone of Silent Valley national park to conserve genetic diversity at low altitudinal ranges in Palakkad, Malappurm, Kannur and Kasargod.

3.2.4 *Decalepis arayalpathra* (J.Joseph & V.Chandras.) Venter

3.2.4.1 Introduction

Decalepis arayalpathra (J.Joseph & V.Chandras.) Venter (Table 12; Fig 4) is one of the most important critically endangered medicinal shrubs endangered due to over-exploitation and habitat loss as per reports. The species belongs to the family Apocynaceae and the genus *Decalepis* comprises total five species such as *D. hamiltonii*, *D. arayalpathra*, *D. salicifolia*, *D. khasiana* and *D. nervosa* (Sharma & Shahzad, 2014). This species only occurs in the hilly regions of elevation ranging from 800-1200 m. Its populations are fragmented and gradually declining due to destructive harvesting of the tuberous roots because of its high medicinal value. The population of the species is generally correlated with arid environments or those with seasonal water shortages. *D. arayalpathra* are narrow endemics of poor soils in rocky hill slopes and rock fissures in deciduous and evergreen forests. It have clusters of numerous, fleshy, tuberous roots with a sweet, vanilla-like fragrance.

Table 12. Details of *Decalepis arayalpathra* (J.Joseph & V.Chandras.) Venter.

Synonym	:	*Janakia arayalpathra* J. Joseph & Chandras.
Vernacular name	:	**Mal.** Amrithapala
Family	:	Apocynaceae
Habit	:	Shrub
Habitat & Ecology	:	Rocky hill slopes and rock fissures in deciduous and evergreen forests of elevation ranging from 800-1200 m
IUCN Red list category	:	Critically Endangered
Distribution	:	Endemic to southern Western Ghats
Use	:	Medicinal

D. arayalpathra (J.Joseph & V.Chandras.) Venter has long been recognized by the *Kani* tribe of Kerala, they consider it an important medicinal plant, as reflected in the vernacular name '*amrithapala*', which translates as the plant which gives the milky nectar of immortality. They make use of juice obtained from the tuber as a remedy for peptic ulcer, as a rejuvenating tonic, and to cure for external cancers (Pushpangadan *et al.*, 1990). In traditional Indian medicine, an estimated 90% of the species used for plant-based medicines are collected from wild populations, and roots are the plant organ most commonly used, resulting in destructive harvest since the whole plant must be pulled from the ground. Presently the three peninsular Indian species of *Decalepis* are threatened in the wild, and listed by IUCN as

endangered (*D. hamiltonii*) or evaluated as critically endangered as per IUCN Guidelines (*D. arayalpathra*; Ravikumar and Ved, 2000) due to over-exploitation and habitat loss. Destructive harvesting of the narrow endemics *D. arayalpathra*, particularly vulnerable given their limited distributions, is escalating as their medicinal properties become known.

3.2.4.2 Materials and Methods

Study area

Thiruvananthapuram district of Kerala State lies between 8° 17' and 8° 54' north latitudes and 76° 41' and 77° 17' east longitude, embraces coast of Arabian Sea on the west and Western Ghats in the east. This region receive South West monsoon, North West monsoon and significant summer showers during June-September, October-December and March-May respectively. Thiruvananthapuram district of Kerala has a tropical climate offering a pleasing climate, with an average maximum temperature of 34°C in the months of March, April and May and coldest months in December, January and February with an average minimum temperature of 21°C.

During the initial period (March 2016 – February 2017) total nine sites of *Decalepis arayalpathra* (J.Joseph & V.Chandras.) Venter was located from Thiruvananthapuram district distributed in Neyyar Wild Life Sanctuary, Peppara Wild Life Sanctuary and reserve forests in Thiruvananthapuram forest division such as Ponmudi, Pallippara, Maruthamala para, Bonaccord-Kurisumala, Kuttamala, Sarkar motta, Madhukettan mala, Thodumala and Kozhikkantam. During the second year (March 2017 – February 2018) three of the study sites were re-visited and population mapping and estimation carried out. During the third year, 2 more localities (Kukri para and Vellarada-Kurisumala) were identified and detailed population mapping as well as population estimation of 6 localities were carried out.

Study includes;

- Mapping of rocks using latitude-longitude data collected using Global Positioning System
- Population assessment, analysis and projections

Method chosen for biodiversity mapping

The rocks were mapped using latitude-longitude data collected using Global Positioning System (Garmin: GPSmap 60CSx) receivers. The latitude-longitude values of sampled locations, along with boundary of rocks were imported and overlaid in Google Earth Pro software. After the digitization of data, vector layers were saved in kml format and layers were imported to QGIS software version 3.6.0 for mapping and decoration.

Method chosen for population assessment

After the demarcation of rock boundary, total area of each study sites were split into 10 × 10 m size grids. After that grids were randomly selected from the location for the population assessment. A quadrat of size 5 × 5 m area was chosen for the population study, number of candidate species, number of adult plants, average number of branches, average number of leaves, average height, number of seedlings and their associated species data were taken. Along with that, threat to the species through anthropogenic, animal attack and environmental stress were studied. Details of 15 localities are given in Table 13.

Table 13. Details of study area

Sl. No.	Latitude	Longitude	Altitude	Location	Forest section/range/ Division
1	8.758317	77.11185	904	Ponmudi*	Kallar/ Palode/ Tvm
2	8.6887	77.12985	199	Maruthamala para*	Vithura/ Paruthippally/Tvm
3	8.68275	77.15052	735	Bonaccad, Kurisumala*	Thodayar/ Peppara WLS/ Tvm WL
4	8.50344	77.17572	2'4	Kuttamala, Amboori*	Revenue land, Amboori
5	8.728683	77.13912	820	Pallipara, Ponmudi*	Kallar/ Palode/ Tvm
6	8.733417	77.09813	746	Sarkarmotta, Kallar	Kallar/ Palode/ Tvm
7	8.52025	77.19692	313	Kozhikkantam	Kilamala-1/ Neyyar WLS/Tvm WL
8	8.5272	77.20515	520	Madhukottan mala*	Kilamala-1/ Neyyar WLS/Tvm WL
9	8.517683	77.2013	476	Thodumala*	Kilamala-1/ Neyyar WLS/Tvm WL
10	8.508067	77.23295	460	Kallippara*	Kilamala-2/ Neyyar WLS/Tvm WL
11	8.511083	77.2114	590	Kukrippara*	Kilamala-2/ Neyyar WLS/Tvm WL
12	8.46440	77.2246	300-600	Vellarada, Kurisumala	Revenue/ Private land, Tvm
13	8.7328	77.10493	800	Varayadu motta	Kallar/ Palode/ Tvm
14	8.51883	77.20517	600	Thodumala-2	Kilamala-1/ Neyyar WLS/Tvm WL
15	8.471675	77.20730278	400	Kundakotti	Revenue/ Private land, Thekkupara, Amboori Tvm

*Detailed study on population carried out

3.2.4.3 Observations

3.2.4.3.1 Population mapping

Among the 14 locations, nine sites were studied elaborately (Table 13; Figs 45,46). This includes population study and mapping of distributed area. In each study area *D. aravalpathra* population was assessed taking 5 × 5 m quadrats. All the 9 localities subjected to detailed study are surrounded by natural vegetation located in protected areas of reserved forests, sanctuaries, revenue land or private land in Thiruvananthapuram district. In all the 14 populations identified significant numbers of *D. aravalpathra* could be identified.

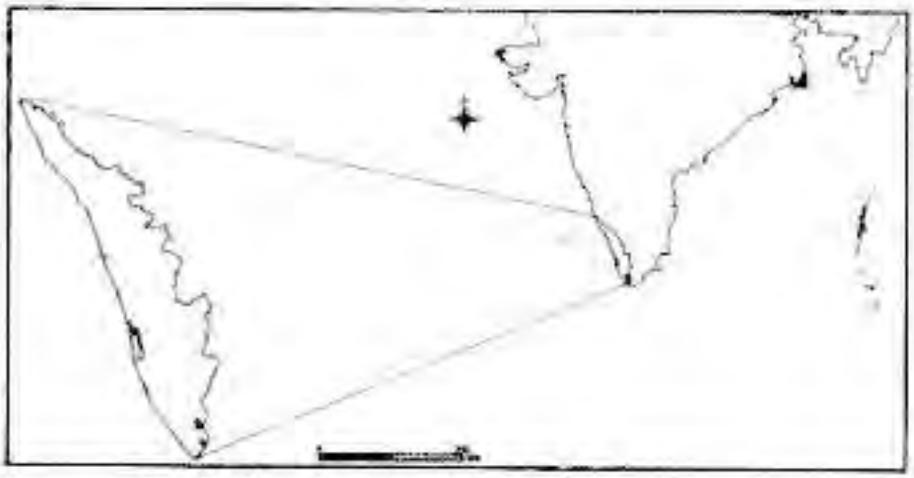

Fig 45. Location map of Study area

Fig 46. Google earth view of *D. aravalpathra* locations

3.2.4.3.2. Population of *D. aryalpathra* in mapped locations

3.2.4.3.2.1 Bonacord-Kurisumalai

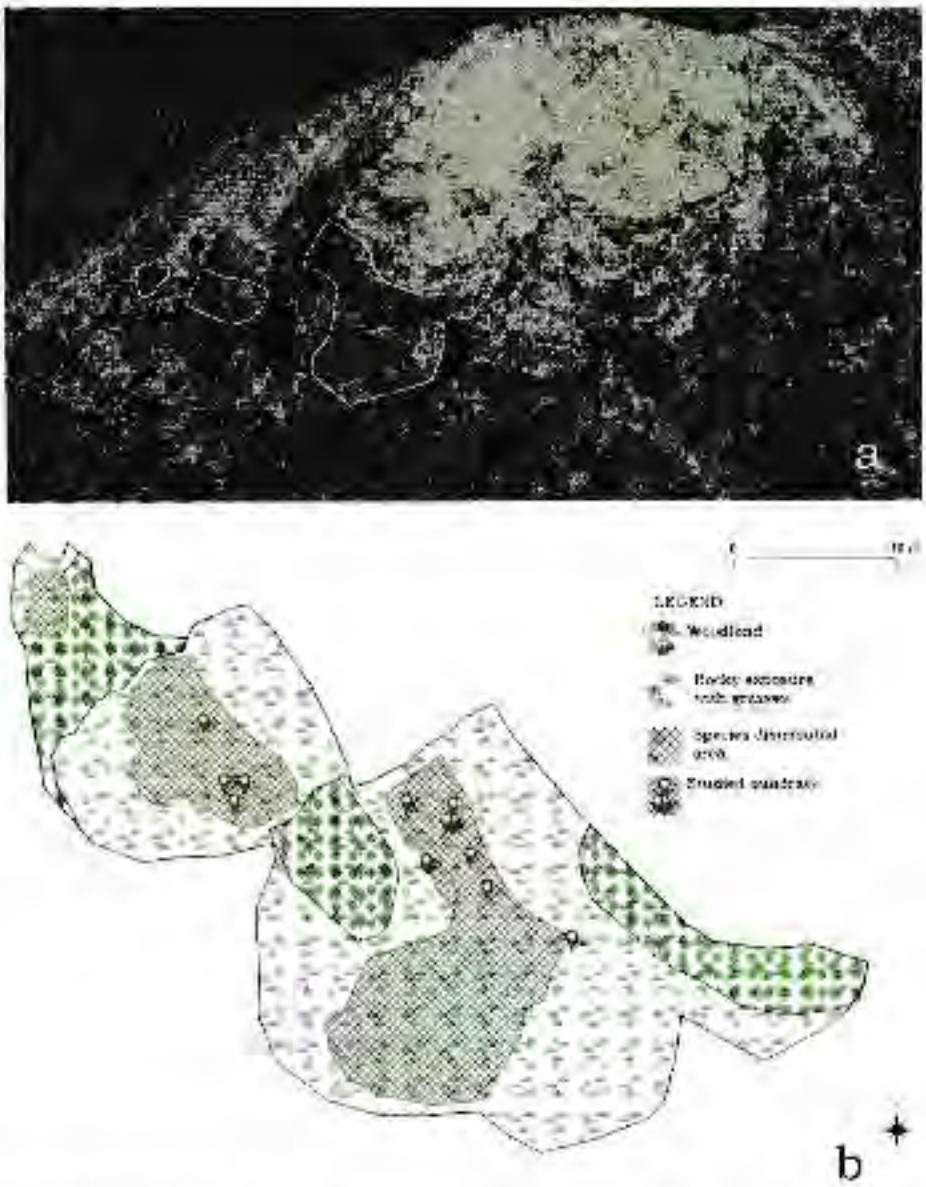

Fig 47. Bonaccad-Kurisumala, the type locality of *D. aryalpathra* in peppara Wildlife Sanctuary. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area

The study was started in the type locality Kurisumalai near Bonaccad estate (875m altitude 77° 10'-77°.11' E 8°41' N (Kew Record; K000197004) presently belonging to Thodayar Forest section of Peppara Wildlife sanctuary of Thiruvnanthpuram Wildlife Division. We identified the populations in 3 patches at 700-735m altitude around 77.15032 E 8.68275N coordinates (Fig 47). The plants distributed are on rocky exposures and exhibited luxuriant growth often with flower and fruits (Fig 48). A total of 12 random quadrats of 5x5m area,

also representing barren rocks in the inaccessible slopes were sampled. Barren rocks in inaccessible rocky exposures were marked by the help of binocular, GPS and Google earth. Thus the total sampled area is 300sqm belonging to a total of 3489sqm plant distributed area (Fig 47). The marked area is having continuous distribution *D. arayalpathra*. The candidate

Fig 48. *D. arayalpathra* in Bonaccord-Kurisumala

plants were present in isolation (less than 25 numbers), in nearby points that were not counted for population estimation. Such points were interrupted by shola formation or grassland with tall grasses, but no rocky exposures (Fig 47). A total of 74 adults comprising of 50 old plants having an average 168.2 branches (Fig 48b,c) and 24 new plants having an average 34.9 branches could be scored in the studied quadrats. The adults were with flowers and attain 75-200cm tall possessing 2-140 branches. Those growing on rocky exposures with sufficient soil grew luxuriantly with large number of branches (Fig 48). However those grow on rocky crevices showed stunted growth with lesser number of branches (Fig 49). Plants less than 1m height and not having branches were not found to have flowers. Such plants were treated as seedlings (new recruits). A total of 5 such seedlings with an average 12.5cm height were recorded in the studied quadrats.

Fig. 49. *D. aravalpathra* in rocky crevices showing less number of branches and stunted growth

Summary of Population at Ponmudi- Kurisumalai

Total plant distributed area:	3489sqm
Total area sampled:	300sqm
Total number of adults:	74
Total number of seedlings:	5

3.2.4.3.2.2 Pallippara

Pallippara with coordinates 77.13912 E 8.728683N is located near Ponmudi under Kallar Forest section of Palode range belonging to Thiruvananthapuram Forest Division, with 820m altitude at the top (Fig 50). Pallippara is a hill with steep rock in the eastern and western sides but shola formation in the north and south sides (Fig 50) and the rocky exposures end in woodland in all sides at about 600m altitude. *D. aravalpathra* is distributed on rocky exposures in the west and east sides (Fig 51a-e). As the candidate species is distributed on two sides, Pallippara have the largest plant distributed area of 59,459sqm. A total of 51 random quadrats each with 25sqm were sampled in accessible rocks. In addition, 12 quadrates from barren rocks in inaccessible slopes were also taken to represent the entire plant distributed area. A total of 214 adults and 101 saplings could be scored in the 1575sqm sampled area. The plants were not evenly distributed but more abundant on the availability of top soil on the rocky exposures. Rich population of saplings could be identified in small islands of concavity on rocks with dominant grasses as *Garnotia* sp (Fig 51d,e). The adult

plants have an average height of 142cm and possessed an average 18.86 number of branches. The seedlings were not having branches but have average 30.8cm height. Largest number of seedlings and adults with lesser number of branches is a clear indication of population establishment at this locality. In addition, this location comes under a reserve forest with least

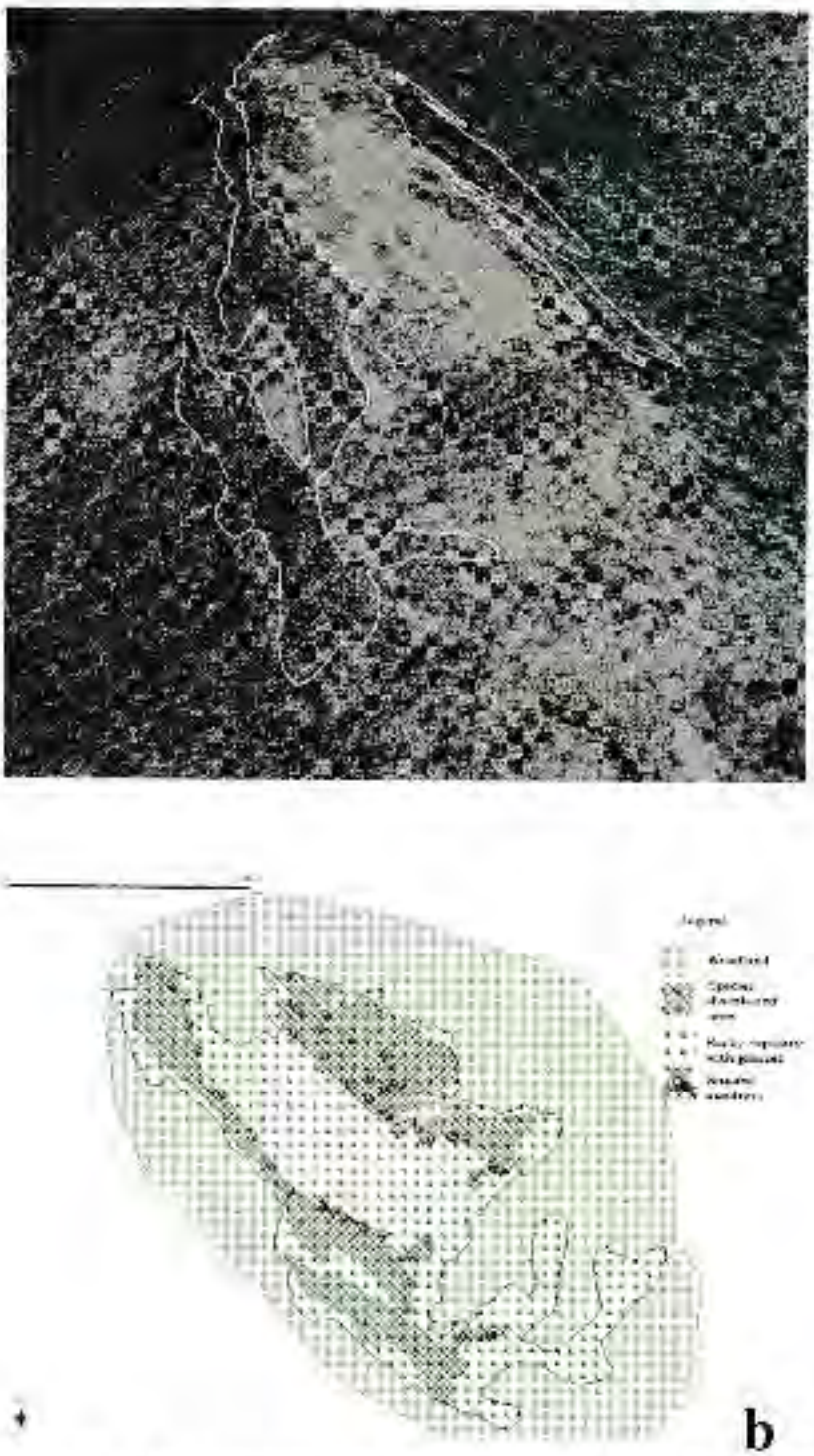

Fig 50. Pallippara in Kallar Forest section of Thiruvananthapuram forest division having distribution of *D. arayalpthra*. a. Google earth view; the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area.

anthropogenic pressures and not easily accessible. There is also no indication of population decline in this location as evident from our visit during 2008, 2016, 2017 and 2019 periods. However, detailed study on population dynamics was not undertaken.

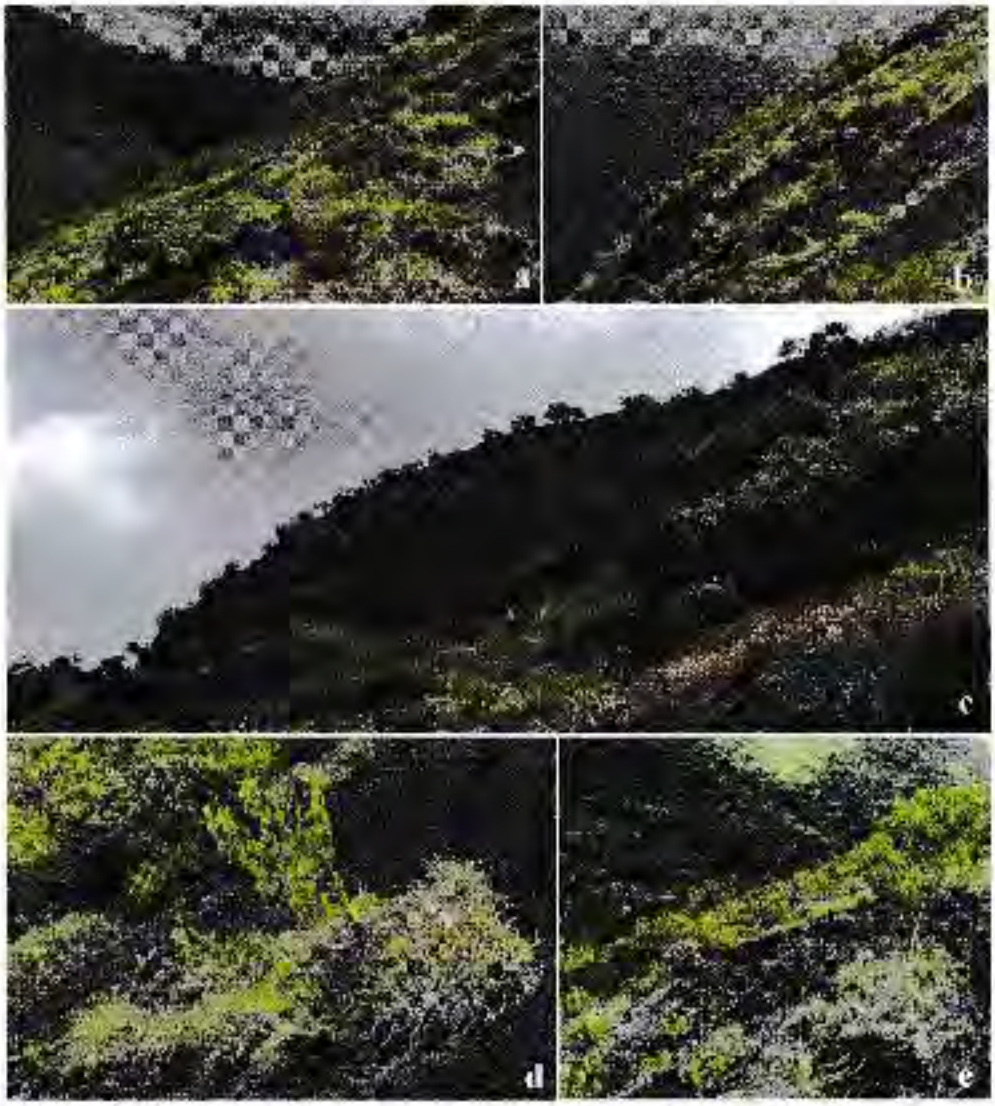

Fig. 51. *D. oroyalpatha* in Pallippara. a. Western slope, b. Eastern slope, c. A rocky exposure with abundant distribution of the species, d,e. Small grassy island on rocks with the establishment of new population

Summary of Population at Pallippara-Ponmudi

Total plant distributed area:	59,459sqm
Total area sampled:	575sqm
Total number of adults:	214
Total number of seedlings:	01

3.2.4.3.2.3 Ponmudi

The location in Ponmudi is at 904m altitude with coordinates 77.11185° E and 8.758317°N belonging to Kallar forest section of Pulode range belonging to Thiruvananthapuram forest Division (Fig 52). This is the location with lowest distributed area and least number of plants. The whole plant distributed area (950sqm) was sampled and the plants scored. There were 31 adults and 6 saplings observed in this location. The adult plants have an average height of 80cm with 16.3 branches (Fig 53). The saplings were average 15cm tall. Relatively lesser number of branches indicates that the population at Ponmudi is a recent formation. There is no indication of decline of the population based on our observation in 2008 and 2017.

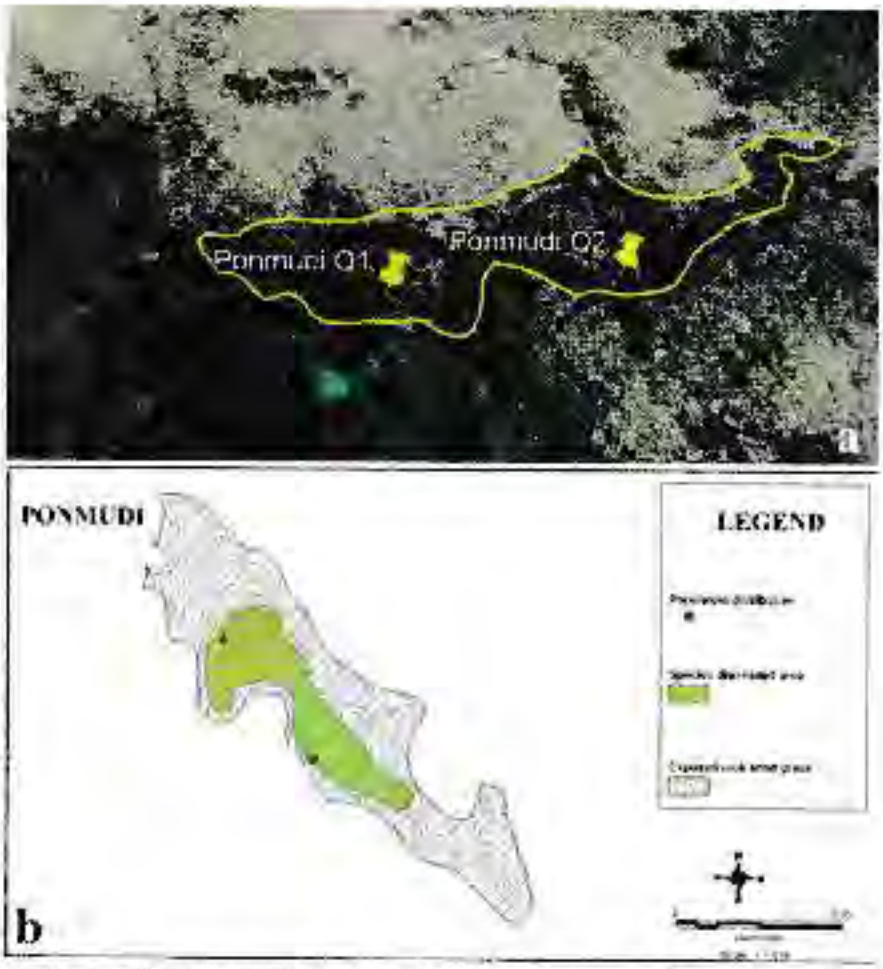

Fig 52. Ponmudi, the locality with least number of *D. aranalpathra* in Kallar Forest Section of Thiruvananthapuram Forest Division a. Google earth view; the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area

Summary of Population at Ponmudi

Total plant distributed area:	950sqm
Total area sampled:	950sqm
Total number of adults:	31
Total number of seedlings:	5

Fig 53. The location of *D. aravalpathra* distribution at Ponmudi

3.2.4.3.2.4 Maruthamala para

Maruthamala para is located at 77.12985°E 8.6887°N close to IISER campus and Narakathinkala tribal settlement in Vithura Forest section of Paruthippally range belonging to Thiruvananthapuram Forest Division. This location is the lowest altitudinal range of 132-242m where *D. aravalpathra* is distributed. This hill range has exposed rocks in three sides except north. The top region is mostly covered by woodland interrupted by grasslands with tall grasses (Fig 54). *D. aravalpathra* has its dominant population in The West slope is easily accessible before the establishment of IISER campus and thus the population of *D. aravalpathra* declined here retaining about 50 individuals, when visited in 2017. Detailed population study was undertaken in the Western slope taking 31 quadrates of 2x2 sqm and 22 quadrates of 5x5sqm. Therefore a total of 674sqm was sampled from 10,600sqm *D. aravalpathra* distributed area. Distribution of *D. aravalpathra* was not evenly distributed as in other localities especially in barren rocks where it has distribution in small islands of grass inhabitation (Fig 55). However, it possessed more even distribution in less inclined slopes with continuous inhabitation by dominant grasses as *Garnotia* sp (Fig 56). In the sampled

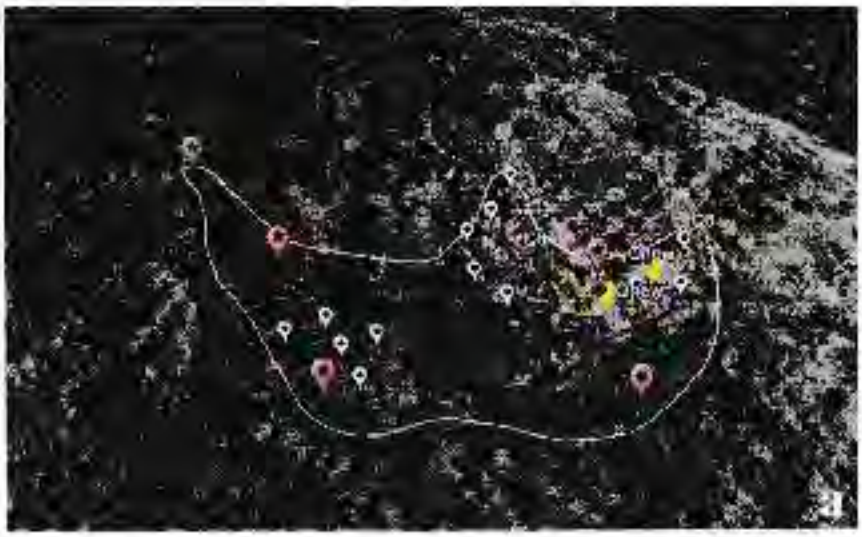

Fig 54a. Google earth view of Maruthamala Para, the locality of low altitudinal range of distribution of *D. aravalpathra* in Vithura Forest section of Thiruvananthapuram Forest Division.

Fig 54b. Topography map of Maruthamala Para. the locality of low altitudinal range of distribution of *D. arayalpathra* in Vithura Forest section of Thiruvananthapuram Forest Division.

area (674sqm). 148 adults and 40 seedlings could be scored. The adults were with an average 39.8 number of branches ranging between 0-200 (Fig 58) and an average 112.3cm height in the range 65-200cm. The seedlings (Fig 57) were 10cm to 100cm tall with an average 20.8cm, usually without having branches.

Fig 55. Localized distribution of *D. arayalpathra* in barren rocks in grassy patches

Fig 56. Distribution of *D. aravalpathra* in less inclined slopes with more soil deposition.

Fig 57. New recruits not attained reproductive maturity, at Maruthamala para

Summary of Population at Maruthamala para

Total plant distributed area:	10,600sqm
Total area sampled:	674sqm
Total number of adults:	148
Total number of seedlings:	10

Fig 58. *D. aryalpathra* at Maruthamala para having mature plants with no branches (a), a few branches (b) and large number of branches (c).

3.2.4.3.2.5 Kuttamala

This is a location outside forest located in Amboori, Thiruvananthapuram. Locally known as Njantupara, this hill range is situated at 77.17572° E and 8.50344°E. It is said to be a revenue land surrounded by rubber plantations. *D. aryalpathra* is distributed at altitudes 213-295m in

the North-West slope in two adjacent hills with intervening woodland dominated by rubber plantation. A total of 6,085sqm is having *D. aravalpathra* distribution and marked based on boundaries marked using GPS (Fig 59). We sampled 11 quadrats in both hills to get a total 275sqm area. Significant number of adults (47) and seedlings (16) could be identified from the sampled area (Fig 60). The adults were with 1-170 branches (Average 30.5) and 75-200cm height (Av 170cm). The seedlings were 10-90cm tall showing an average 23cm.

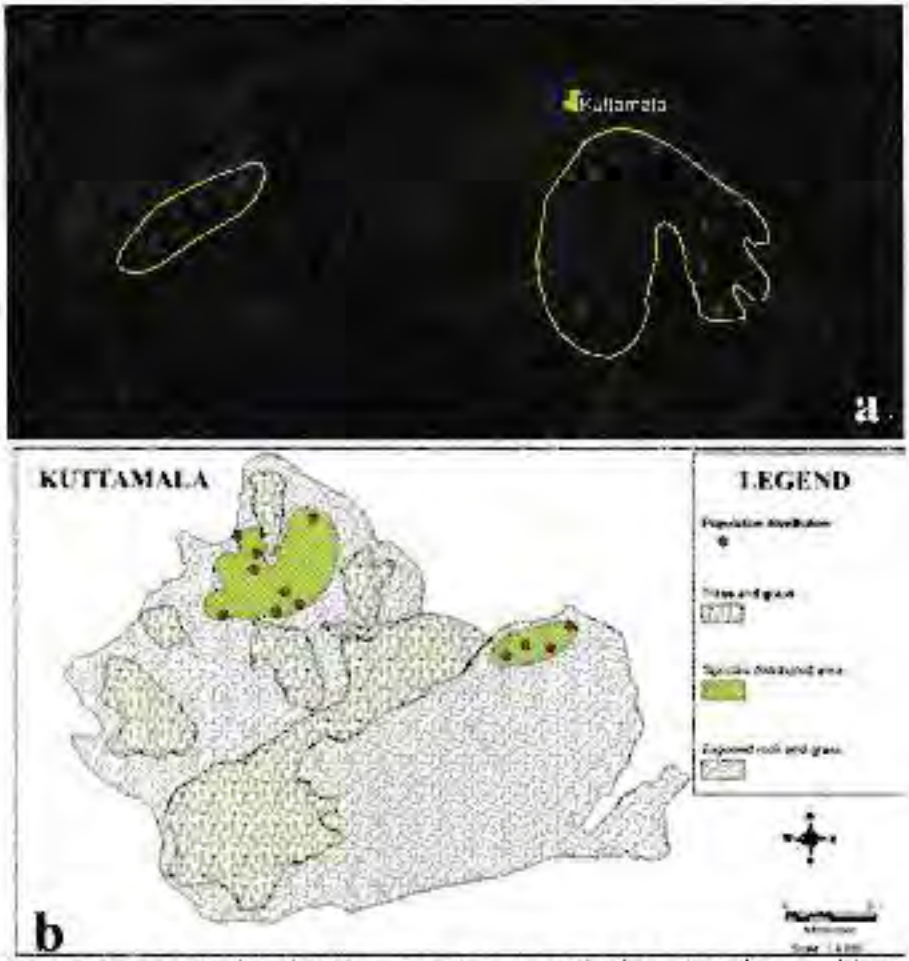

Fig 59. Kuttamala, near Amboori, Thiruvananthapuram district, a location outside Forest, in a revenue land having distribution of *D. aravalpathra*. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species: b. topography map of the distribution area

Fig. 60. *D. aravalpathra* population at Kuttamala

There was a clear indication of formation of new population (Fig 61) as evidenced by new recruits and plants with new stem and lesser number of branches (Fig 61). In the latter locality, plants with flowers were seldom observed compared to the nearby old populations holding average 30.5 branches with average 170cm height (Fig 60). Therefore, it is evident that the population of *D. arayalpathra* is gradually spreading to the nearest location (Fig 61).

Fig 61. Spread of population into area adjacent to existing population with individuals having large number of branches. a. area of formation of new population. b-d. Succession from seedlings to that attained reproductive maturity but with only two branches.

Summary of Population at Kuttamala

Total plant distributed area:	6,085sqm
Total area sampled:	275sqm
Total number of adults:	47
Total number of seedlings:	16

3.2.4.3.2.6 Thodumala

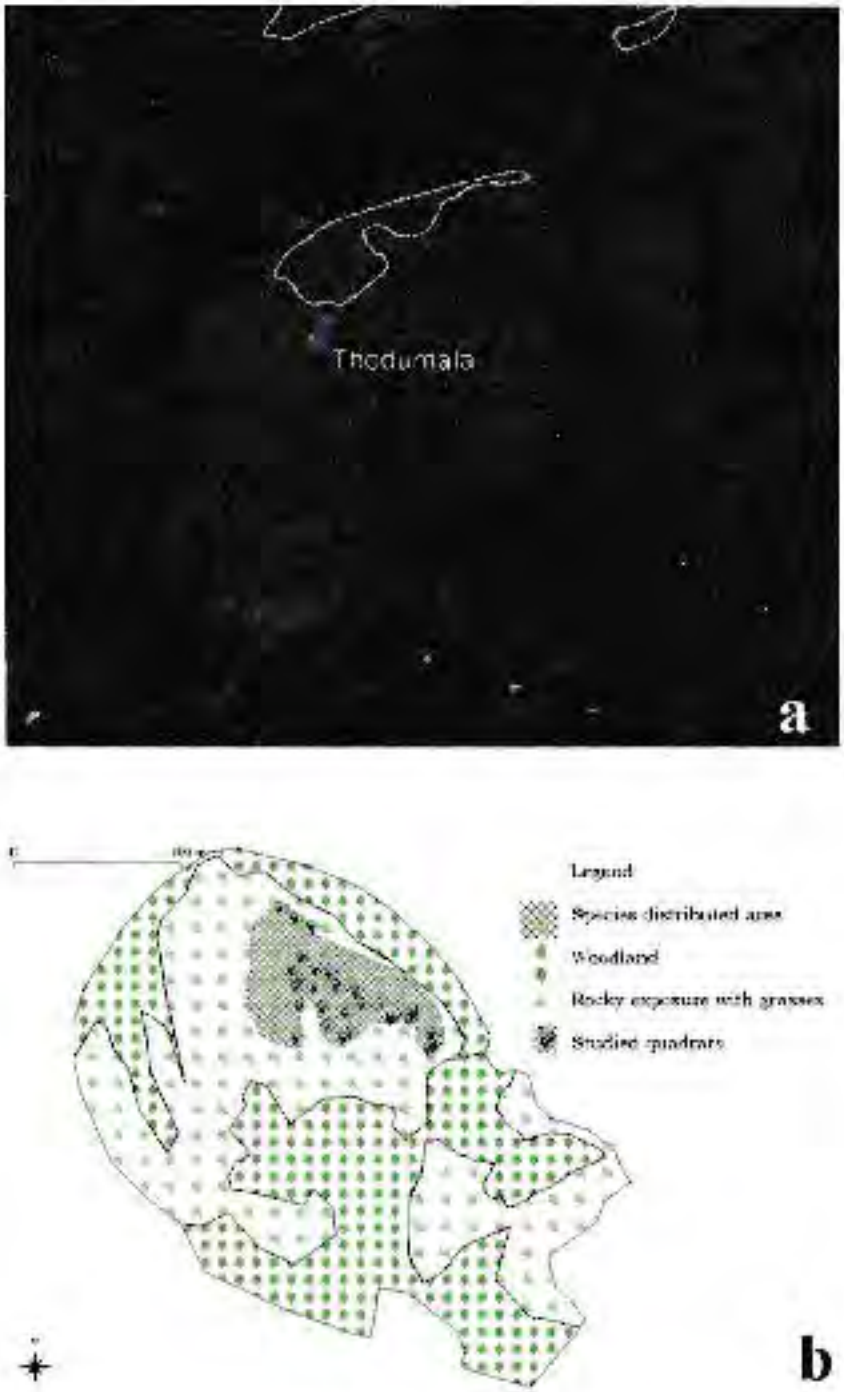

Fig 62. Thodumala in Neyyar WLS having distribution of *D. arayalpathra*. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area

It is situated at 77.2013°E and 8.51768°N very close to Karikkuzhi in Kilamala-1 forest section of Neyyar Wildlife Sanctuary of Thiruvananthapuram Wildlife division. *D. arayalpathra* is distributed in the North-West slope having inaccessible steep rocks and undulating rocky exposures with small slopes inhabited with grasses and shrubs (Fig 62). Dense population is present in the small slopes (Fig 63). Despite, it was difficult to study the

populations in the steep slopes, presence of *D. arayalpathra* could be confirmed using binoculars and photographed using 20x zoom camera (Fig 64). In the latter locality, *D. arayalpathra* used to inhabit small patch of dominant grass *Garnotia* sp.. The grass seems to hold seeds of *D. arayalpathra* and allow them to germinate. The grass also provides physical support to anchor the roots in addition holding organic matter to nourish the seedlings (Fig 65). The seedlings have large tubers and are through which they evade extreme dry conditions, storing sufficient water (Fig 65d).

Fig 63. Dense population of *D. arayalpathra* identified in Thodumala

D. arayalpathra is distributed at altitudes 450-488m in an area of about 25,775sqm. A total of 650sqm was sampled through 26 quadrates including represented area from barren rocks devoid of any vegetation. Altogether 98 plants including 81 adults and 17 saplings could be

scored from this locality. The adults possessed an average 176m height (100-350cm) with average 36.5 branches (6-140). The saplings were 15-50cm tall having an average 21cm.

Fig 64. *D. ovoidpatho a* in inaccessible slopes in Thodumala

Summary of Population at Thodumala

Total plant distributed area:	25,775sqm
Total area sampled:	650sqm
Total number of adults:	81
Total number of seedlings:	17

Fig 65a-e. Seedlings anchored by grasses, d. Tuber formation in seedlings, embedded in grassy patches or rocky crevices.

3.2.4.3.2.7 Mathikettan mala

It is situated at 77.20515°E and 8.5272°N very close to Kunnathumala in Kilamala-1 forest section of Neyyar Wildlife Sanctuary of Thiruvananthapuram Wildlife division (Fig 66). This is the second largest plant distributed area studied. *D. arayalpathra* is distributed in the West and east slopes. West slope consists of inaccessible steep rocks thus presence was confirmed through binocular observation and photography using zoom camera. However a few quadrates along boundaries could be studied. As in thodumala, *D. arayalpathra* used to inhabit small patch of dominant grass *Garnotia* sp. in the steep rocks (Fig 67). East slope is more accessible and have more even distribution of the species (Fig 68). *D. arayalpathra* is distributed at altitudes 373-523m in an area of 32,704sqm. A total of 1025sqm was sampled

through 41 quadrates including 11 from barren rocks devoid of any vegetation to represent blank area for the purpose of population estimation.

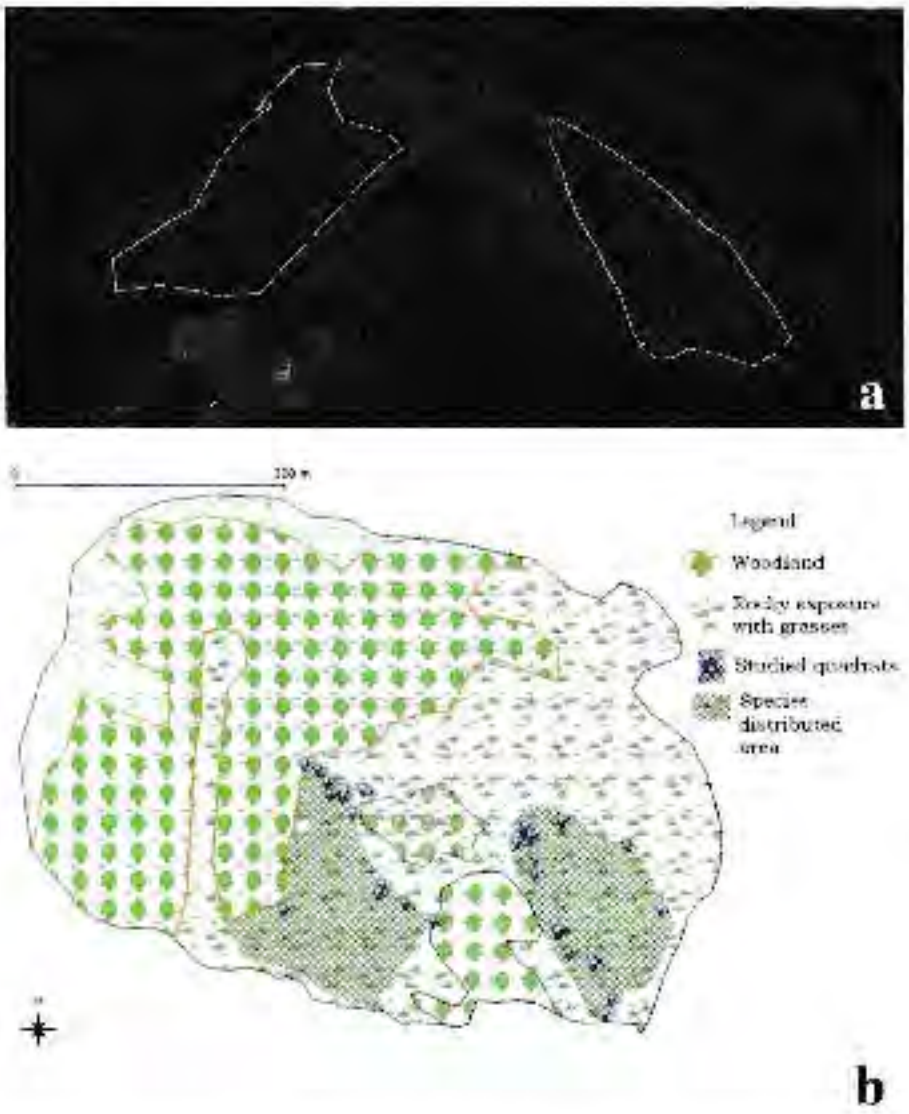

Fig 66. Mathikettan mala in Neyyar WLS having distribution of *D. arcuolpathra*. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area.

Altogether 81 plants including 71 adults and 10 saplings could be scored from this locality. The adults possessed an average 110cm height (40-300cm) with average 33.4 branches (6-157). Saplings were relatively less in this location.

Summary of Population at Mathikettan mala

Total plant distributed area:	52,704sqm
Total area sampled:	1025sqm
Total number of adults:	81
Total number of seedlings:	10

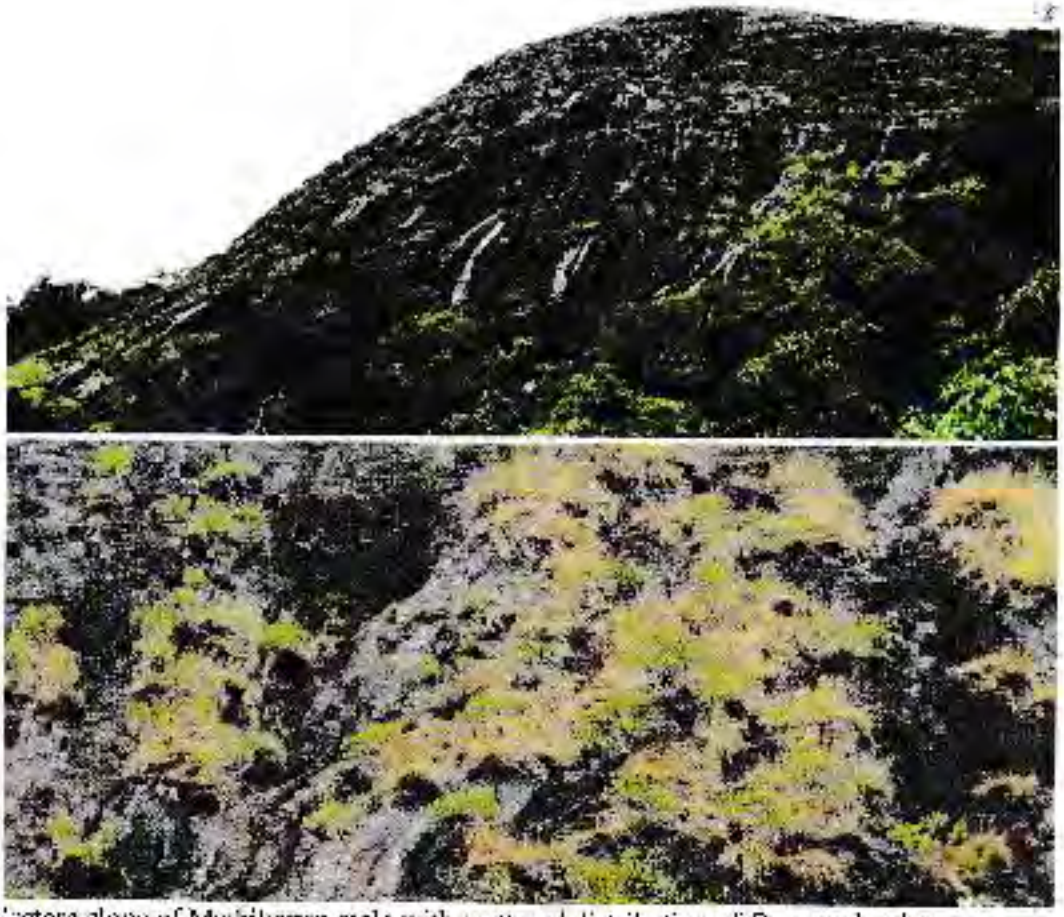

Fig 67. Western slope of Mathikettan mala with scattered distribution of *D. aravalpathra*

Fig 68. Less inclined Eastern slope of Mathikettan mala with abundant distribution of *D. aravalpathra*

3.2.4.3.2.8 Kallippara

It is situated at77.23295°E and 8.508067°N very close to Ananiruthi forest station in Kilamala-2 forest section of Neyyar Wildlife Sanctuary of Thiruvananthapuram Wildlife division (Fig 69). This is the longest patch of plant distributed area studied. Some area in the

location even looks like a desert habitat with many succulents (Fig 70). However, *D. aryalpathra* is distributed in the east slopes but not associated with such succulents. *D. aryalpathra* is distributed at altitudes 446-460m in an area of 37,795sqm. A total of 1250sqm was sampled through 50 quadrates.

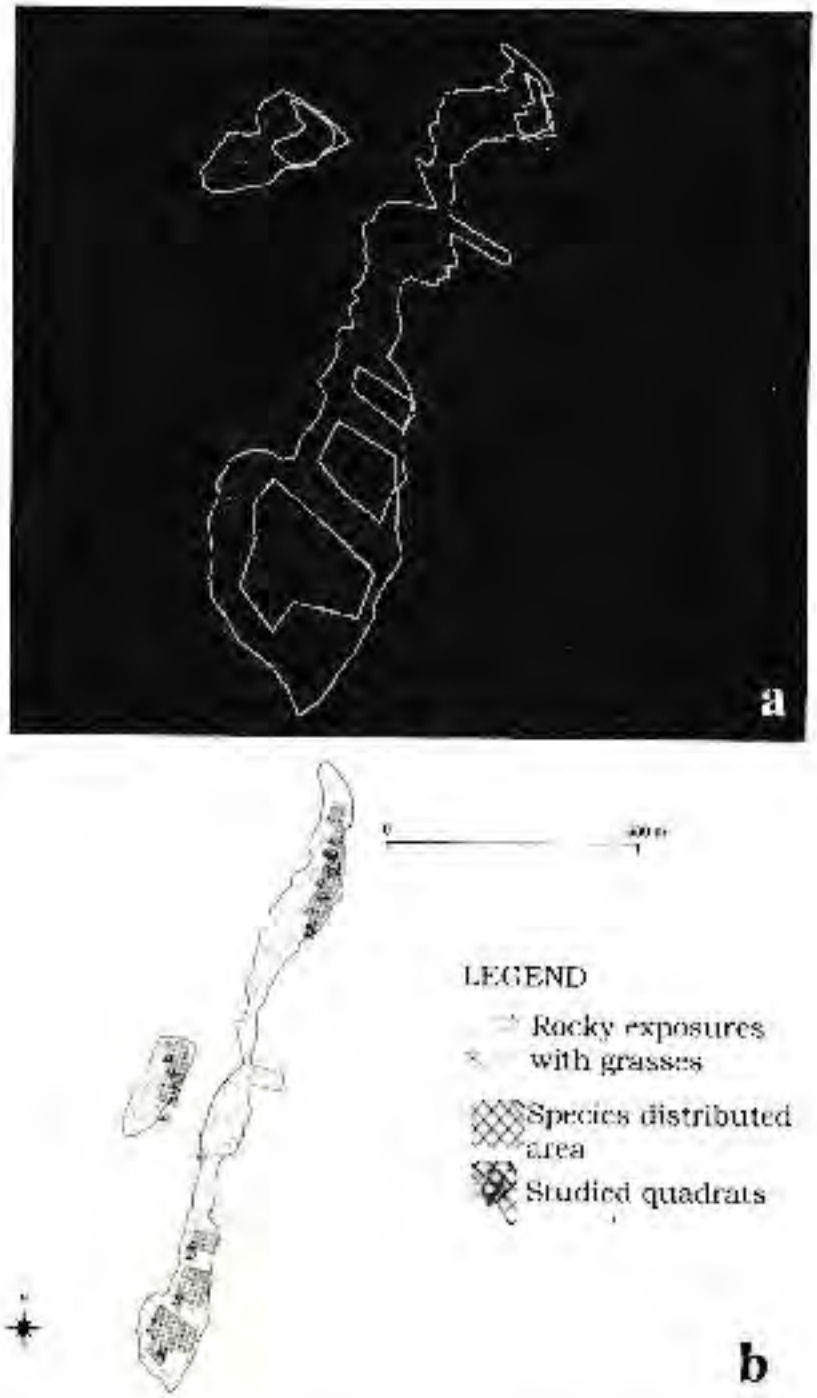

Fig 69. Kallippara in Neyyar WLS having distribution of *D. aryalpathra*. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species; b. topography map of the distribution area

Altogether 117 plants including 102 adults and 15 saplings could be scored from this locality. As this site was visited in February, the dry season, the seedlings were not visible. Still, 15 seedlings could be located in all the quadrates. The adults possessed an average 145.8cm height with average 13.2 branches. Suplings were with an average height 48.6cm. Small seedlings were not visible due to the absence of leaves.

Fig. 70. Kallippara with *D. aravalpathra* distribution

Summary of Population at Kallippara

Total plant distributed area:	37,795sqm
Total area sampled:	1250sqm
Total number of adults:	102
Total number of seedlings:	15

3.2.4.3.2.9 Kukrippara

It is situated at 77.2114°E and 8.511083°N in Kilamala-2 forest section of Neyyar Wildlife Sanctuary of Thiruvananthapuram Wildlife division (Fig 71). *D. aravalpathra* is distributed in the South-east slopes in close association with *Garnoria sp.* (Fig 70). *D. aravalpathra* is distributed at altitudes 423-590m in an area of 8,414sqm in two adjacent rocks. A total of 225sqm was sampled through 9 quadrates. *D. aravalpathra* was distributed in less density so that only 16 adults and 4 saplings were scored from 225sqm sampled area. As this site was visited in March, the dry season, the seedlings were not visible. Still, 4 seedlings could be

located in all the quadrates. The adults possessed an average 136.3cm height with average 14 branches. Saplings were with an average height 45cm. Small seedlings were not visible due to the absence of leaves.

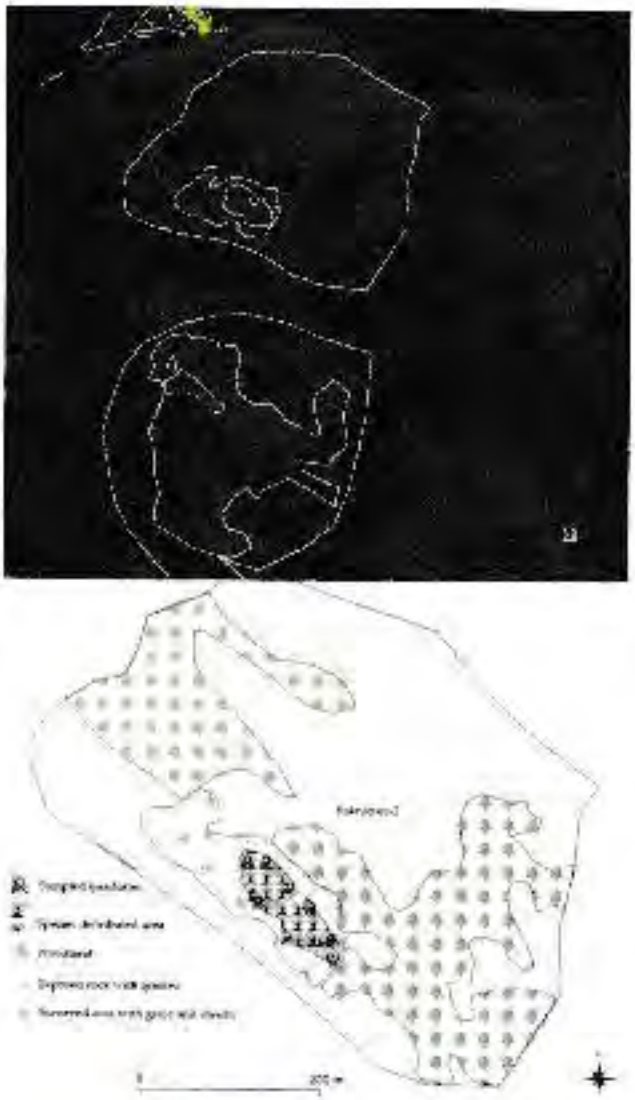

Fig 71. Kukri para in Neyyar WLS having distribution of *D. areyolpathra*. a. Google earth view: the area inside the marked boundary line represent the distribution area of the candidate species: b. topography map of the distribution area

Summary of Population at Kukrippara

Total plant distributed area: 8,414sqm
Total area sampled: 225sqm
Total number of adults: 16
Total number of seedlings: -

3.2.4.3.3 Projections of populations in locations subjected to detailed study

The population studies have been completed in nine sites and population strength has been projected based on those recorded from random quadrates. Altogether, 2,05,271 sqm area has been mapped as the total area of *D. arevalpathra* distribution and 6,050 sqm as the total sampled area. A total of 606 adults and 165 saplings with single shoots of less than 1 m height that did not flower were observed in the sampled area (Table 14). A population of 22,068 adults and 6,803 is projected in all the 9 localities. As the distribution of plant is not random and area in inaccessible slopes could not be studied, the projected score may not match with actual population. Also, the plant distribution area provided is only topographical and the actual area is still higher as the land is highly undulating slopes of about 30-80°. However, blank areas in inaccessible slopes are represented by random quadrates taken using Google earth map. Therefore, the projection is anticipated to be close to actual population.

Table 14. Details of population studied in different localities

Sl. No	Study area	Extended species distributed area (m^2)	Total area sampled (m^2)	Status of candidate species	Projected number of individuals in the whole study area
1	Banacead-Kurismmala	3,489	300	74adults 5saplings	860adults 58 saplings
2	Pallipara	59,459	1,575	214adults 101saplings	7898 adults 4124 saplings
3	Pammudi*	950	950	31 adults 6 saplings	31 adults 6 saplings
4	Maruthamala para*	10,600	674	148 adults 40 saplings	2305 adults 629 saplings
5	Kuttamala*	6,085	275	47 adults 16 saplings	1039 adults 354 saplings
6	Thodumala	25,775	650	81 adults 17saplings	3212 adults 674 saplings
7	Mathikettan mala	52,704	1025	71 adults 10 saplings	3690 adults 536 saplings
8	Kallippara	37,795	1250	102 adults 15 saplings	2612 adults 327 saplings
9	Kukrippara	8,414	225	16adults	421adults

				4saplings	95saplings
Total		2,05,271	6,050	784 adults 214 saplings	22,068 adults 6,803 saplings

Saplings – Plants with single shoots of less than 1 m height not reached flowering stage

Another 932 number of plants have been reported from 4 locations in KMTR (Malleshappa, 2013)

3.2.4.3.4 *D. aarayalpathra* in other locations

In addition to the 9 locations subjected to detailed study, 6 other localities (Table 13) were also identified by visit to the localities or through binocular observations. The localities Sarkar motta, Vellarada-Kurisumala and Kozhikkantam mala (Fig 72a-c) were visited once and observed the populations. However, the other locations Kondaketti (Fig 72d), Thodumala-2 and Varayadu motta (Fig 73a-d) were examined using binoculars and confirmed the presence of *D. arayalpathra* (Fig 73). In all localities, significant number of *D. arayalpathra* is present, even though in lesser densities.

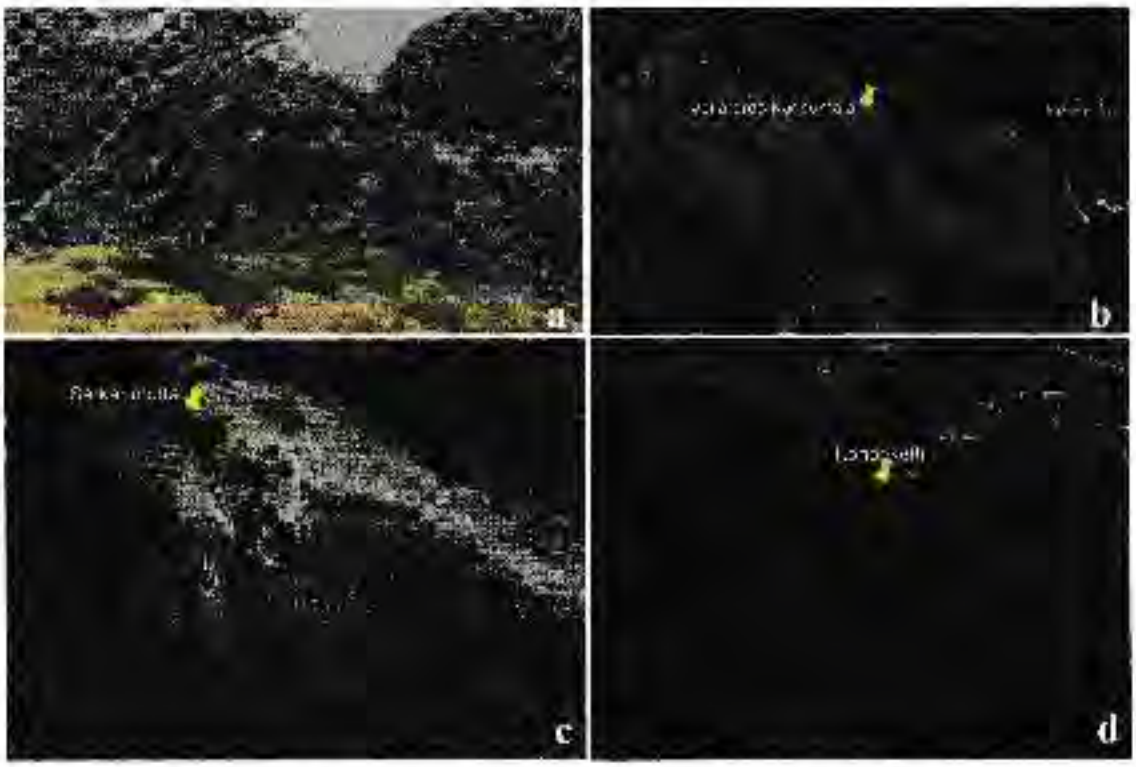

Fig 72. Other locations where *D. arayalpathra* populations were identified. a. Kozhikkkantam mala near Kunnathumala in Neyyar W.L.S, b. Vellarada Kurisumala (Private/Revenue land) near Vellarada in Thiruvananthapuram Dist, Kerala/KK Dist TN. c. Sarkar mutta, Kallar Forest section, Tvm forest Division. d. Kondketti near thekkupara, Amboori

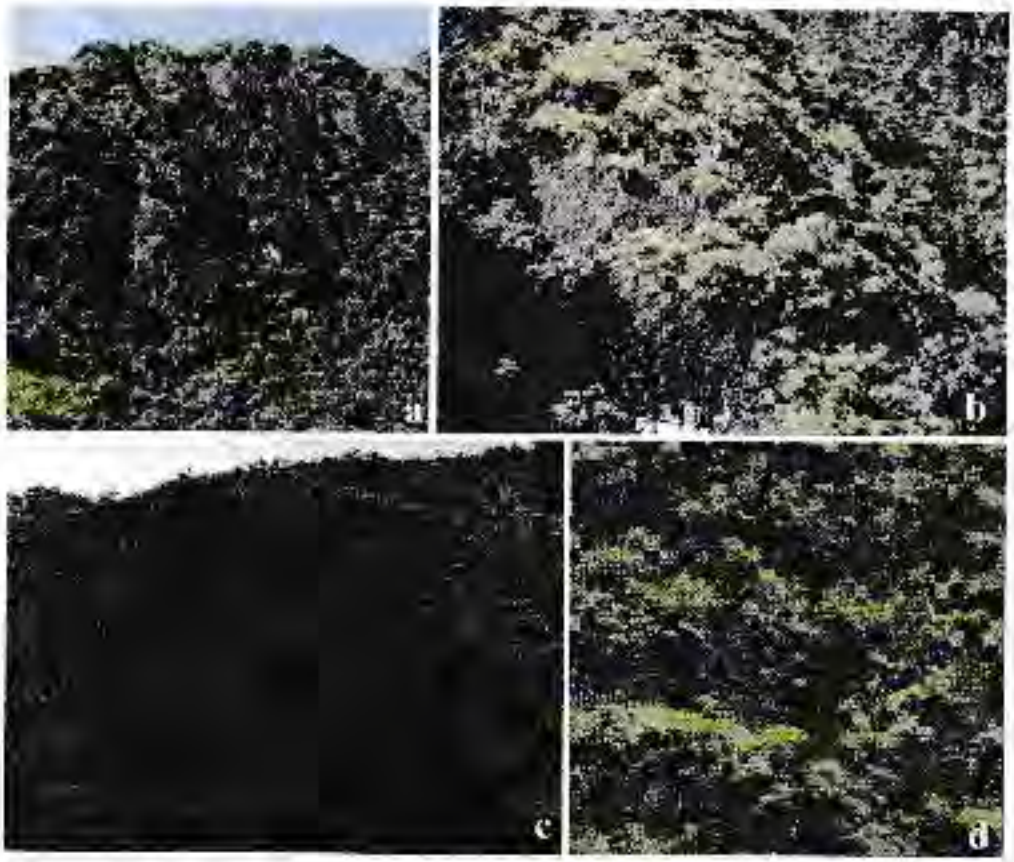

Fig 73a,b. Varayadu motta, c,d. Thodumala-2 having distribution of *D. aravalpathra*.

3.2.4.3.5 Detailed population diversity analysis

Species heterogeneity

Species heterogeneity gives an idea about the organization of community in an ecosystem. This is estimated on the basis of diversity, dominance and evenness of the species in a community. Diversity measurement was done by Shannon index (H'), Simpson index was used for dominance and Pielou index was used for evenness (Table 15). Habitat of *D. aravalpathra* is entirely different from the ecosystems like evergreen, deciduous or other forest formations; it is present in the exposed rocks along with grasses and other bushy species. In this current study among the nine study sites, Ponmudi and Kallippara have the highest species diversity (1.8566 and 1.7298) due to the lesser dominance of *D. aravalpathra*. But Simpson's dominance index is higher in Thodumala (0.4039) and Kukrippara (0.4324) proving that *D. aravalpathra* is present more in Thodumala and Kukrippara.

Table 15. Diversity, dominance and evenness indices of different populations

Study area	Shannon diversity	Simpson's dominance	Pielou evenness
Maruthamala para	1.2715	0.3285	0.7900
Kuttamala	0.9599	0.2111	0.4169
Ponmudi	1.3566	0.2004	0.8063
Kukrippara	1.2237	0.4324	0.6289
Thodumala	1.27	0.4059	0.6527
Mathikettan Mala	1.2171	0.3678	0.7562
Kallippara	1.7298	0.2013	0.8889
Pallippara	1.4423	0.3144	0.5804
Bonaccad-Kurisumala	1.259	0.3148	0.9082

Relative density and relative frequency can visualize the dominance of species in study area. In the case of relative density and relative frequency of *D. aravalpathra*, it was higher in Pallippara with 37.5 and 40 and Maruthamala para with 20.9 and 37.3 respectively it proves that *D. aravalpathra* has successively colonized in Pallippara and Maruthamala para than other sites. Among the nine study sites Ponmudi is having lowest relative density and relative frequency as 14.3 and 13.3 respectively (Table 16).

Table.16 Relative density and relative frequency of *D. aravalpathra*

Study area	Relative density	Relative frequency
Maruthamala para	20.9	37.3
Kuttamala	36.9	29.4
Ponmudi	14.3	13.3
Kukrippara	7.81	26.31
Thodumala	9.17	27.27
Mathikettan Mala	5.51	24.19
Kallippara	8.29	22.81
Pallippara	37.5	40
Bonaccad-Kurisumala	27.77	33.33

For understanding the growth pattern of *D. aravalpathra* in different study location, population was monitored in different seasons. Number of adult plants, average number branches, number of seedlings and average height of seedlings were noted. Table 17 depicts the growth pattern of *D. aravalpathra* in different localities. During dry period commencing from December, the plants wither their leaves (Table 18; Fig 74) and sprout after getting summer showers in March-April.

Table 17. Growth characters of sample plants scored among different populations during May- November 2016-19

Study area	Adult plants	Average no. of branches	Av. leaf/ branch	Average height (cm)	No. of seedlings	Average height of seedlings (cm)
Pallippara	221	18.86	25-80	142.3	98	30.85
Ponmudi	28	16.3	18	79.5	14	15
Bonaccord. Kuriscmala	74	101.55	25-80	99.8	5	12.5
Maruthamala para	142	39.8	25-80	112.3	55	20.8
Madhuketan mala	25	33.4	25-80	110	2	10
Thodumala	62	56.5	25-80	176	10	21
Sarkarmotta	91	23.3	25-80	101.2	5	21.7
Kuttamala	41	22.5	25.5	170	16	23

Table 18. Growth characters of sample plants scored among different populations during dry period. Observation made in February during 2016-19.

Study area	Adult plants	Average no. of branches	Average no. of leaves/ Branch	Average height (cm)	No. of seedlings	Average height of seedlings (cm)
Madhuketan Mala	52	9.2		152.6	7	84.3
Thodumala	20	5.4		137.5	7	37.5
Kallippara	175	13.2	17	145.8	18	48.6
Kukrippara	16	14		136.3	4	45
Kuttamala	32	13	3.5	163	11	39.4
Pallippara	53	3.6	5.9	83	1	30

Fig 74. Appearance of *D. urcyalpathra* during dry period in January-February season

Most of the associated species of *D. arayalpathra* are shrubs and herbs; trees are hardly associated with the candidate species (Table 19). Because of the extreme climatic conditions only a few species were noted as associates, among them more common are *Garnotia* sp, *Ischaemum* sp, *Chrysopogon sp* and bushy shrub *Osbeckia aspera*. These three species are playing a good role in the succession of *Decalepis arayalpathra* in bare rocks. In all the quadrats scored, *Ischaemum* sp and *Osbeckia aspera* were associated with *D. arayalpathra*. However two species of *Garnotia* are dominant in all quadrates on barren rocks (Fig 75). Table 19 depicts the relative density and relative frequency of associated species in different study area.

Table 19. Relative density and relative frequency of associated species

Study area	Species name	Relative density	Relative frequency
Kalippara	*Garnotia sp*	25.52	19.29
	Arundina bambusifolia	10.52	8.77
	Exacum sp	8.15	15.78
	Osbeckia aspera (L.) Blume	16.45	19.35
Malhikettan Mala	*Chrysopogon sp*	89.75	24.19
	Oldenlandia sp		16.12
	Exacum sp	7.5	16.12
	Ischaemum sp	7.36	18.18
	Osbeckia aspera (L.) Blume	7.09	18.18
	Garnotia sp	37.9	18.18
Thodumala	*Coleus forskolii*	0.54	3.03
	Exacum sp	2.72	12.12
	Sarcostemma sp	1.09	3.03
	Ischaemum sp	7.89	10.52
	Osbeckia aspera (L.) Blume	6.31	23.68
	Garnotia sp	42.63	23.68
Kokrippara	*Coleus forskolii*	1.05	5.26
	Exacum sp	3.68	7.89
	Sarcostemma sp	0.52	2.63
	Ischaemum sp	95.16	16.7
	Osbeckia aspera (L.) Blume	6.33	9.28
	Garnotia sp	156.22	13.92
	Arundina baminsifolia	20.82	4.64
Pallipara	*Vernonia multibracteata*	1.22	1.85
	Fimbristylis spp.	2.65	5.56
	Breynia rhamnoides	6.73	10.89
	Stylocoryne canarica	1.63	3.71
	Exacum sp	2.04	3.71
	Osbeckia aspera (L.) Blume	6.73	4.64
	Garnotia sp	37.59	28.57

Fig 75. Two species of *Garnotia* give support to growth and establishment of *D. ravalpathra* common to all localities

The bare rocks are made difficult in early colonization of *D. aravalpathra*. However, the roots system of *Garnotia sp* helps in weathering of bare rock and accumulation of organic matter supporting *D. aravalpathra* to colonize in the rock easily. The saplings and seedlings observed were close to or in the *Garnotia sp* bunch because of moisture and weathered rock soil. This probably helps the colonization of new members of *D. aravalpathra* in early stages. Apart from *Garnotia sp* and *Osbeckia aspera* some of the associated species were seasonal like *Ceropegia spiralis* Wight, *Eriocaulon* sp., *Utricularia reticulate* Sm. etc. A common checklist of associated species scored in different study area is showed in Table 20.

Table 20. Common checklist of associated species of *D. aravalpathra*

Sl. No:	Species name	Family
1	*Garnotia sp*	Poaceae
2	*Arundina graminifolia* (D. Don) Hochr.	Orchidaceae
3	*Ceropegia spiralis* Wight	Apocynaceae
4	*Chrysopogon sp*	Poaceae
5	*Coleus forskalii*	Lamiaceae
6	*Cymbopogon* sp.	Poaceae

7	*Dendrobium herbatulum*	Orchidaceae
8	*Dendrobium wightii* A. D. Hawkes & A. H. Heller	Orchidaceae
9	*Dioscorea bulbifera* L.	Dioscoreaceae
10	*Drosera indica* L.	Droseraceae
11	*Elymus repens* (L.) Gould	Poaceae
12	*Eriocaulon* sp.	Eriocaulaceae
13	*Eulophia epidendrea*	Orchidaceae
14	*Exacum sp*	Gentianaceae
15	*Iris sp*	Iridaceae
16	*Ischaemum* sp.	Poaceae
17	*Osbeckia aspera* (L.) Blume	Melastomaceae
18	*Sarcostema brevistigma*	Asclepiadaceae
19	*Strobilanthes ciliatus* Wall. ex Nees	Acanthaceae
20	*Stylocoryne zeylanica*	
21	*Tabernaemontana alternifolia* L.	Apocynaceae
22	*Utricularia reticulata* Sm.	Lentibulariaceae
23	*Ziziphus oenoplia* (L.) Miller	Rhamnaceae
24	*Arundinella sp*	Poaceae
25	*Themeda sp*	Poaceae

3.2.4.3.6 Population threat

Detailed study on population dynamics could not be undertaken. However, the observations on visit to various localities during various periods from 2008 to 2019 indicate no significant decline in most of the localities. In a few localities as Maruthamala para (east slope) and Sarkar mottu, decline of population due to collection was evident as significant numbers of plants distributed in the easily accessible spots found disappeared.

Probably due to stored water in the tubers, wild animals as wild boar seem to feed on the tubers of *D. oryzaeoides* especially during dry period. The remnants of tuber and droppings of wild boar could be identified in Maruthamala para, Kottamala, and Ponmudi (Fig 76). After the tuber being completely eaten by the animals the plants fall down. Some of the plants re-establish through new sprouts if part of root system still exists. Rarely the plants were found fallen by detaching from rocky surface along with grasses due to environmental

factors as heavy water flow or weathering of rocks. However, these are environmental factors and such depletion is less than the establishment of new recruits.

Fig 75. Threat to *D. oroxylopatora* populations. a. a plant uprooted and showing regeneration after the tubers were eaten by wild boar, b-d. plants uprooted due to natural reasons, probably animal movement, e. uprooted plant fell into the bottom of rocky hill in Maruthamala para. f-h. plant destruction after the tuber eaten by wild boar. f. One plant cleared by wild boar, g. remaining of tuber, h. droppings of wild boar observed in the latter location in Maruthamala para.

3.2.4.3.7 Assessment of threat status based on IUCN Guide lines

At present the species is evaluated as critically endangered (Ravikumar and Ved 2000). A taxon is Critically Endangered when the best available evidence indicates that it meets the criteria A to E (Annexure-I).

However the present study revealed to consider the species under **Vulnerable category**.

Assessment information

- No significant population reduction due to any of the factors observed in the locations subjected to observations/detailed study during 2008 to 2019
- No population reduction or anticipated in the next 10 years as most of the locations with abundant distributions are in protected forests and significant numbers of new recruits also present. The plants also seem to evade the risk of forest fire through their embedded tuberous root system in rock crevices and grass clumps.
- Extent of occurrence is more than 1000Km^2. Population identified in more than 15 localities in Kerala at distance 2.74 to26Km from its type locality, Bonaccord-Kurisumala (Table 21) in Kerala region and up to 50Km in Tamil Nadu region (Table 21) as per the coordinates given in published reports. Population is discrete as the climatic suitability is restricted to rocky exposures but continuous in the occurrence locations.
- Estimation of area of occupancy is incomplete. Out of the 24 known locations, only 9 locations could be estimated constituting only 0.24 Km^2 area.
- Population size more than 250 mature individuals. No continuing decline to the level of 25%. All the visited populations have more than 50 mature individuals. Fluctuations in number of mature individual is negligible.
- Quantitative analysis not undertaken but there is less than 50% probability of extinction in the wild within 10-20years based on our observations since 1998
- Population size estimated to number more than 2,500 mature individuals and no population decline observed or projected and 8 populations estimated to contain more than 250 mature individuals. No extreme fluctuation in number of mature individuals noticed.
- Conclusion: *D. orayolpathra* does not meet the criteria A-D to place under Endangered Criteria. May be included as Vulnerable B1a-B2a Version 3.10

Table 21. Population distance from Bonaccord-Kurisumala, the type locality

Sl. No.	Location	Map distance (Km)*	Direction
1	Bonaccord-Kurisumala	0	
2	Maruthamala para2	2.74	Towards North
3	Pallippara-Ponmudi	5.46	
4	Varayadumotta	7.41	
5	Sarkarmotta	7.87	
6	Ponmudi	9.64	
7	Mathiketan mala	18.26	Towards South
8	Thoduma.a	18.98	
9	Kozhikkantam mala	18.64	
10	Thodumla-2	19.05	
11	Kuttamala	20.41	

12	Kukrippara	20.59	
13	Kallippara	21.92	
14	Kondaketti	24.29	
15	Vellarada-Kurisumala	26.11	
16	Aduppukkulmottai	12.81	Toward East (TN) Priyanka *et al* 2015
17	Kutharaikattimettai	23.67	
18	Nadokandamparai	24	
19	Amman Kovilmottai	24.26	
20	Vishnumottai	43.97	
21	Manamalai	40.97	
22	Pallvarakadavu	46.69	
23	Yanaisethaoddaimadai	47.29	
24	Asambu	50.96	
Extent of distribution= 1082 Km^2 (approx)			
Area of occupancy in 9 locations 0.25 Km^2			

3.2.4.3.8 Distribution modeling of *Decalepis arayalpathra*

To find potential distribution of *D. arayalpathra* in unknown localities, ecological niche modeling was performed using maximum entropy (maxent; http://www.cs.princeton.edu/~schapire/maxent/; Philips *et al* 2004, 2006) modeling software. Geographical coordinates (Table 22) at 1Km resolution obtained during our field surveys and those reported earlier (Priyanka *et al* 2015) were used for this study.

Table. 22. *D. arayalpathra* populations at 1Km resolution used for population distribution modeling.

Sl. No	Latitude	Longitude	Altitude	Location	Forest section/ Division/sanctuary
1	8.758316667	77.11185	904	Ponmudi	Tvm
2	8.6887	77.12985	199	Maruthamala para	Tvm
3	8.68275	77.15051667	735	Bonaccord-Kurisumala	Peppara
4	8.689383333	77.12741667	252	Maruthamala Para	Tvm
5	8.728683333	77.13911667	830	Pallippara	Tvm
6	8.727433333	77.14123333	793	Pallippara	Tvm
7	8.728333333	77.1002	785	Sarkarmotta	Tvm
8	8.733416667	77.09813333	746	Sarkarmotta	Tvm
9	8.52025	77.19691667	313	Kozhikkanram	Neyyar
10	8.5272	77.20515	520	Madhukettan	Neyyar
11	8.5251	77.20763333	448	Madhukettan	Neyyar
12	8.517683333	77.2013	476	Thodumala	Neyyar
13	8.576638889	77.34458333	1300	Amman Kovilmettai	KMTR/ Asambu/Mahendrg iri Reserve Forests
14	8.4695	77.48233333	1171	Vishnumottai	
15	8.597527778	77.35111111	1078	Kutharaikattimottai	

16	8.61	77.24169444	1235	Adupukalmottai	Priyanka *et al* 2015
17	8.435194441	77.41344444	733	Muramalai	
18	8.592972222	77.33941667	1419	Nadukandarparai	
19	8.382111111	77.45405556	675	Pallvarakadavu	
20	8.570888889	77.48202778	977	Yanaisethaoddaimadai	
21	8.35775	77.46808333	864	Asambu	
22	8.4641	77.2246	590	Vellrada-Kurisumala	Revenue/private
23	8.4678	77.22473	480	Vellrada-Kurisumala	Revenue/private
24	8.511083	77.2114	590	Kukkripppara	Neyyar
25	8.5084	77.2104	580	Kukkrippara	Neyyar
26	8.508067	77.23295	460	Kallippara	Neyyar
27	8.505	77.23803	490	Kallippara	Neyyar
28	8.5142	77.22956	480	Kallippara	Neyyar
29	8.4717	77.2073	400	Kondaketti	Revenue/private
30	8.7328	77.10493	800	Varayadumotta	Tvm
31	8.5034	77.176	214	Kuttamala	Revenue

Nineteen environmental variables obtained from bioclim.org (Hijmans *et al.*, 2005; http://www.worldclim.org/bioclim.htm) were used for the study. Based on climatic data of occurrences points extracted (used QGIS open source software) correlation analyzed to find co-linearity of environmental variables and discarded/used any one variables showing correlation above 0.95. Also, those variables showing no contributions were omitted to generate final model. Thus 3 variables (Table 23) were retained for final modeling and the model thus obtained was similar to that obtained with all 19 variables (Fig 17).

Table 23. The environmental and elevation variables used and their contribution in the distribution model.

Variables	% Contribution in the model	Permutation importance
BIO15 Precipitation Seasonality (Coefficient of Variation)	50	30.5
BIO2 Mean diurnal range (max temp - min temp) (monthly average)	40.3	67.8
Elevation	9.7	1.7

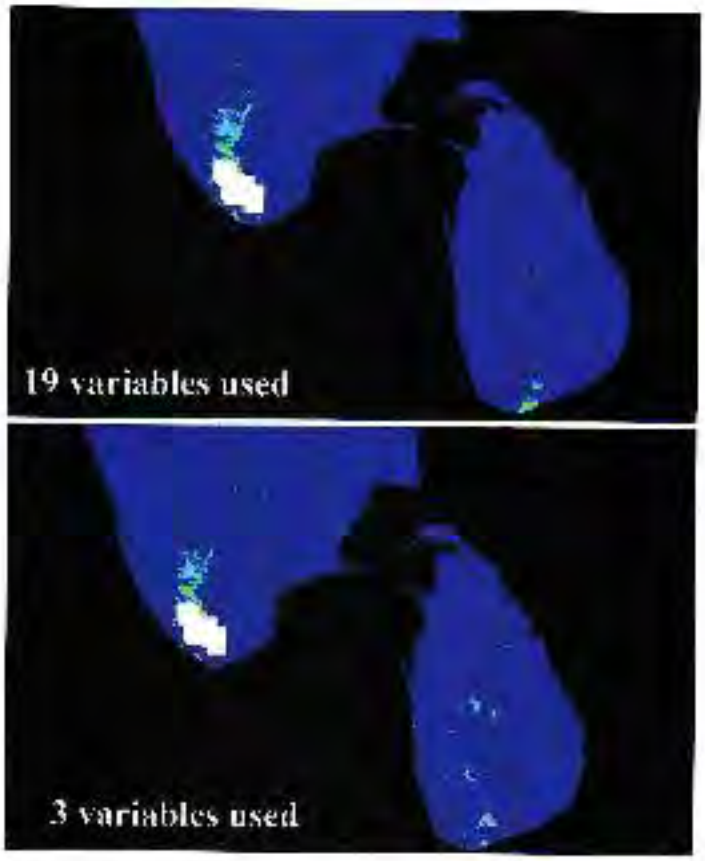

Fig 77. Distribution model generated using maxent softwre with 19 environmental variables (top) and 3 variables selected from the latter 19 variables.

The model indicates potential distribution of the species in Kanyakumari and Thirunelveli Districts of Tamil Nadu and Thiruvnanthapuram and Kollam Districts of Kerala (Fig 78). Pathanamthitta District of Kerala and Sri Lanka are also seemed to have potential habitat for *D. arayalpathra*.

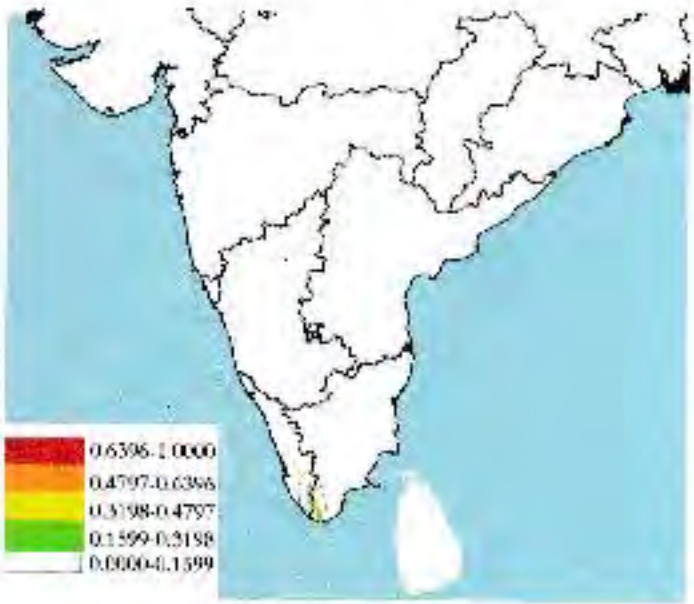

Fig 78a. Distribution model of *D. arayalpathra* generated for peninsular India

Fig 78b. Distribution model of *D. aroyalpthra* generated for peninsular India enlarged to the distribution area. Blue spots indicate the occurrence points

Most of the identified populations belong to 64-100 (11 in red) and 48 to 64% (15 in orange) and 32-48% (3 in yellow) probable areas. Two points fall in the green region (16-32% probable area) (Fig 78a). Besides the omission curve is very close to predicted omission (Fig 78b). None of the occurrence points were omitted from the distribution map. Therefore, the model may be used to trace unknown populations especially in the Shenduruney Wildlife sanctuary and Aryankavu gap region in Kollam district.

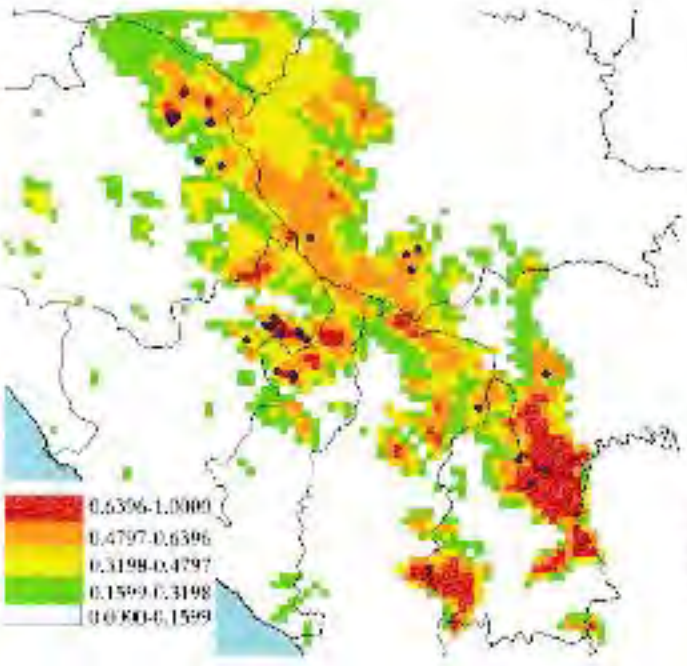

Fig 78a. *D. aroyalpthra* occurrence points in most probable area (red, orange) of distribution model.

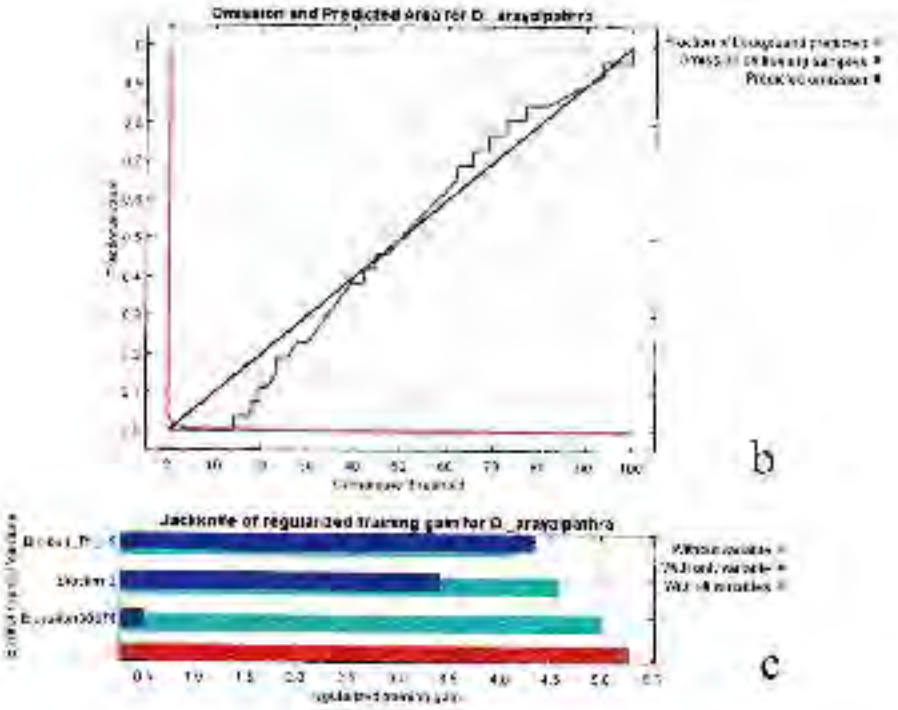

Fig 78.b Graph showing Omission and predicted area of *D. rayalpathra* distribution. c.Jack Knife test showing contributions and importance of 3 variables. Variable Bio15 shows highest training gain by itself and highest reduction when it is omitted and thus appear as the most important variable that determine the distribution of *D. rayalpathra*.

Out of the three variable used Precipitation Seasonality (Coefficient of Variation) have highest contribution in the model (50%). Mean diurnal range (max temp – min temp) (monthly average) also contribute significantly (40.3%) (Table 23). However, altitude has least contribution of only 9.7%. Jackknife test (Fig 78c) indicate that the environmental variable with highest gain when used in isolation is Precipitation Seasonality, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is also the same. Therefore Precipitation Seasonality is also appears to be the most information that isn't present in the other variables. *D. rayalpathra* inhabits the locations where Mean diurnal range (max temp – min temp) (monthly average) remains between 6.08 to 7.17 (Table 24) where annual mean temperature remains between 19.05 and 25.97. Also, precipitation seasonality as the most important determining factor, it should be in the range 53.0-62.5 (average=58.4) with annual precipitation 1650-2449mm. As the coefficient of variation remains at relatively lesser level, the regions appear to receive more or less uniform distribution of rain in the two monsoon seasons. However, elevation is not much influencing its habituation as the species is

distributed at wide ranges as low as 168m to as high as 1482m. Thus the study revealed precipitation seasonality and mean diurnal range are the decisive factors that sustain the populations of *D. arvalipathra*

Table 24. Climatic data of occurrence points extracted using QGIS software

Sl.No	Location		Climatic data at the occurrence points				
	Longitude	Latitude	Annual mean temperature	Mean Diurnal range	Precipitation seasonality	Elevation	Annual precipitation
1	77.11185	8.758317	22.85417	6.525	59.96119	826	2290
2	77.12985	8.6887	25.97917	7.175	55.98027	158	1649
3	77.15052	8.68275	24.00833	6.75	56.12709	557	1925
4	77.12742	8.689383	25.97917	7.175	55.98027	158	1649
5	77.13912	8.728683	23.39167	6.8	57.18312	655	2048
6	77.14125	8.727433	23.39167	6.8	57.18312	655	2048
7	77.1002	8.728333	24.02083	6.675	58.43338	613	2096
8	77.09813	8.733417	23.80417	6.55833	59.34964	673	2178
9	77.19693	8.52025	26.04167	6.85	56.59986	168	1521
10	77.20515	8.5272	25.27917	6.69167	55.41082	347	1657
11	77.20763	8.5251	25.27917	6.69167	55.41082	347	1657
12	77.2013	8.517683	24.9375	6.55833	55.43734	441	1752
13	77.34458	8.576639	19.83333	6.56667	56.02061	1292	2435
14	77.48233	8.4695	20.125	6.48333	54.60777	1363	2449
15	77.35111	8.597528	20.9125	6.54167	53.60897	1119	2170
16	77.24169	8.61	19.05	6.21667	62.58809	1482	2885
17	77.41344	8.435194	22.75	6.63333	52.37408	797	1890
18	77.33942	8.592972	20.57083	6.54167	54.76867	1175	2275
19	77.45406	8.382111	23.9375	6.625	53.01241	662	1650
20	77.48203	8.370889	22.825	6.08333	53.07516	972	2038
21	77.46808	8.35775	23.27083	6.175	53.04743	915	1984
22	77.2246	8.4644	25.96667	6.8	56.39139	243	1548
23	77.22473	8.4678	24.8625	6.49167	55.65464	507	1808
24	77.2114	8.511083	24.08333	6.33333	55.94279	650	1967
25	77.2104	8.5084	24.08333	6.33333	55.94279	650	1967
26	77.23295	8.508067	25.0125	6.64167	55.16153	422	1687
27	77.23803	8.505	24.92917	6.65833	54.81338	437	1688
28	77.22956	8.5142	24.8125	6.60833	54.9444	461	1724
29	77.2073	8.4717	26.09167	6.86667	56.82963	218	1552
30	77.10493	8.7328	24.02083	6.675	58.43338	613	2096
		Average	23.73	6.62	56.01		1940

To understand the influence of precipitation during various seasons as January-March, April May, June-September and November-December was also modeled using the same procedure. A model very close to that obtained above was obtained (Fig 79). However, Precipitation seasonality and Temperature mean diurnal range remained as the most determining factors. Still, precipitation during dry periods (March-May and January February) have more contribution compared to the wet months ie., June-September and October-December (Table 25). It is therefore very clear that small amount of precipitation throughout the year is very important for the sustenance of *D. arayalpthra* (Table 26)

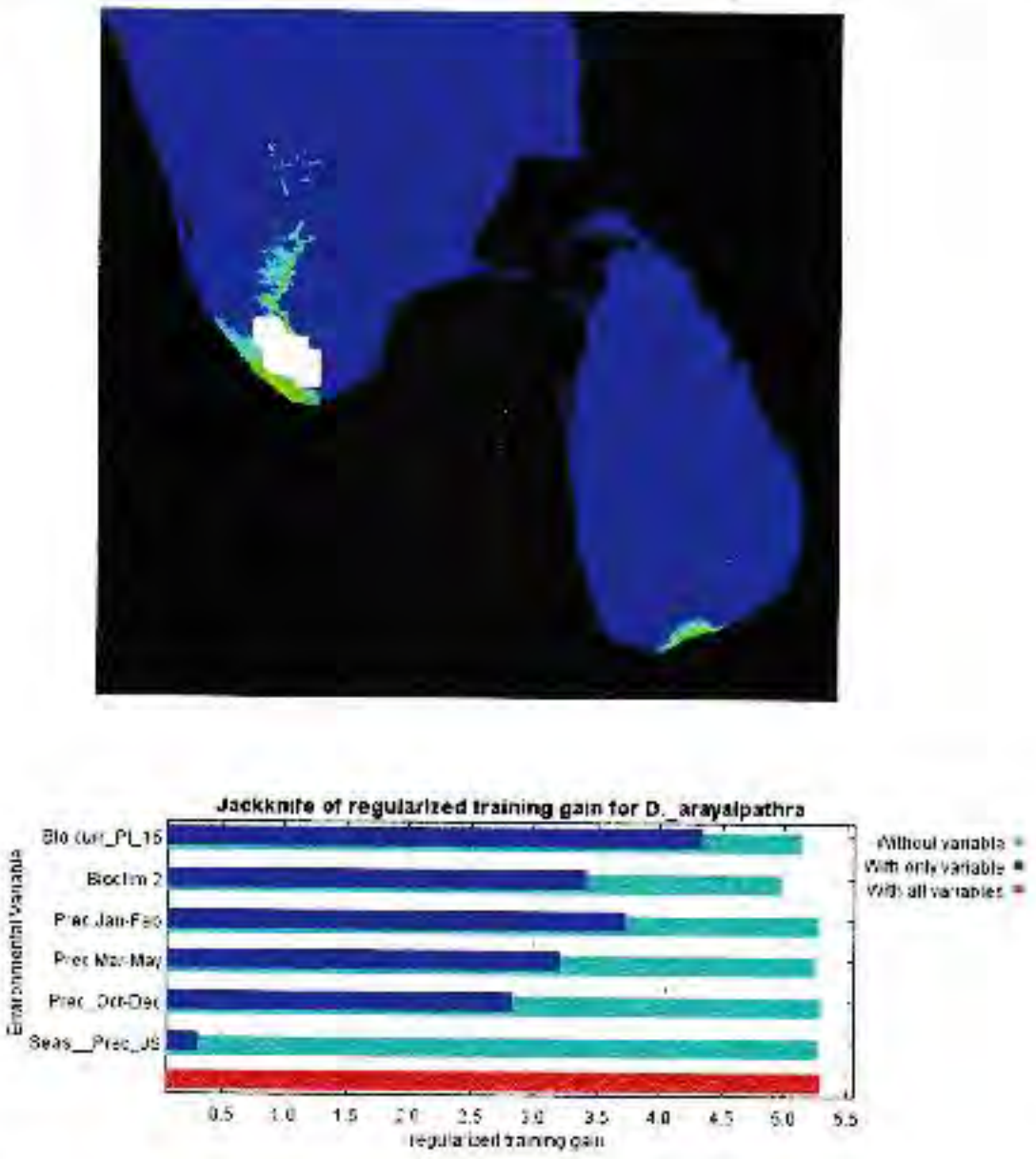

Fig 79. Distribution model of *D. arayalpathra* generated using the environmental variables Precipitation coefficient of variation (15), temperature mean diurnal range (2), Precipitation January–February, Precipitation March-May, Precipitation June-September and Precipitation October-December.

Table 25. Contribution to the model created using precipitation in four seasons and two bioclim factors, Bio2 and Bio15.

Variable	Percent contribution	Permutation importance
Prec March-May	31.9	0.1
Prec January-February	29.2	0.1
Prec_June-September	12.8	0.1
Prec October-December	11.7	0
Precipitation seasonality (Bio 15)	7.5	46.6
Temperature mean diurnal range (Bio2)	6.9	53.1

Table 26. Precipitation in 4 seasons at the occurrence point of *D. arcuvalpatica*.

Sl.No	Location		Precip.tation data at the occurrence points			
	Longitude	Latitude	Prec Jan-Feb	Prec Mar-May	Prec June-Sep	Prec Oct-Dec
1	77.11185	8.758317	92	355	1169	674
2	77.12985	8.6887	67	321	702	559
3	77.15052	8.68275	84	325	888	628
4	77.12742	8.689383	67	321	702	559
5	77.13912	8.728683	87	336	982	643
6	77.14123	8.727433	87	336	982	643
7	77.1002	8.728333	85	344	1027	640
8	77.09813	8.733417	87	350	1090	651
9	77.19692	8.52025	64	293	613	551
10	77.20515	8.5272	73	299	700	585
11	77.20763	8.5251	73	299	700	585
12	77.2013	8.517683	76	306	766	604
13	77.34458	8.576639	111	367	1211	746
14	77.48233	8.4695	116	371	1197	765
15	77.35111	8.597528	105	340	1013	712
16	77.24169	8.61	115	406	1579	785
17	77.41344	8.435194	94	301	763	661
18	77.33942	8.592972	107	350	995	723
19	77.45406	8.382111	87	281	647	635
20	77.48203	8.370889	100	322	914	702
21	77.46808	8.35775	97	317	878	692
22	77.2246	8.4644	66	233	633	561
23	77.22473	8.4678	78	308	807	615
24	77.2114	8.511083	85	323	915	644
25	77.2104	8.5081	85	323	915	644
26	77.23295	8.508067	75	297	718	597

27	77.23803	8.505	77	297	715	599
28	77.22956	8.5142	78	300	741	605
29	77.2073	8.4717	64	291	640	557
30	77.10493	8.7328	85	344	1027	640
Average			85.57	323.7	891	640.2

Future Predictions:

Using the 3 environmental variables, future climatic suitability to sustain the population of *D. aravalpathra* was also prepared using data obtained from worldclim.org for the period 2081-2100 (wc2.1_2.5m_bioc_MIROC6_ssp245_2081-2100). The environmental variable with highest gain when used in isolation is Precipitation seasonality (coefficient of variation) which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is also the same, which therefore appears to have the most information that isn't present in the other variables. The climatic suitability appeared expanding towards north to Idukki District of Kerala (Fig 79a). Therefore, future cultivation may be undertaken in rocky exposures of hill ranges in Kollam, Pathanamthitta, and Idukki Districts of Kerala and adjoining areas in Tamilnadu.

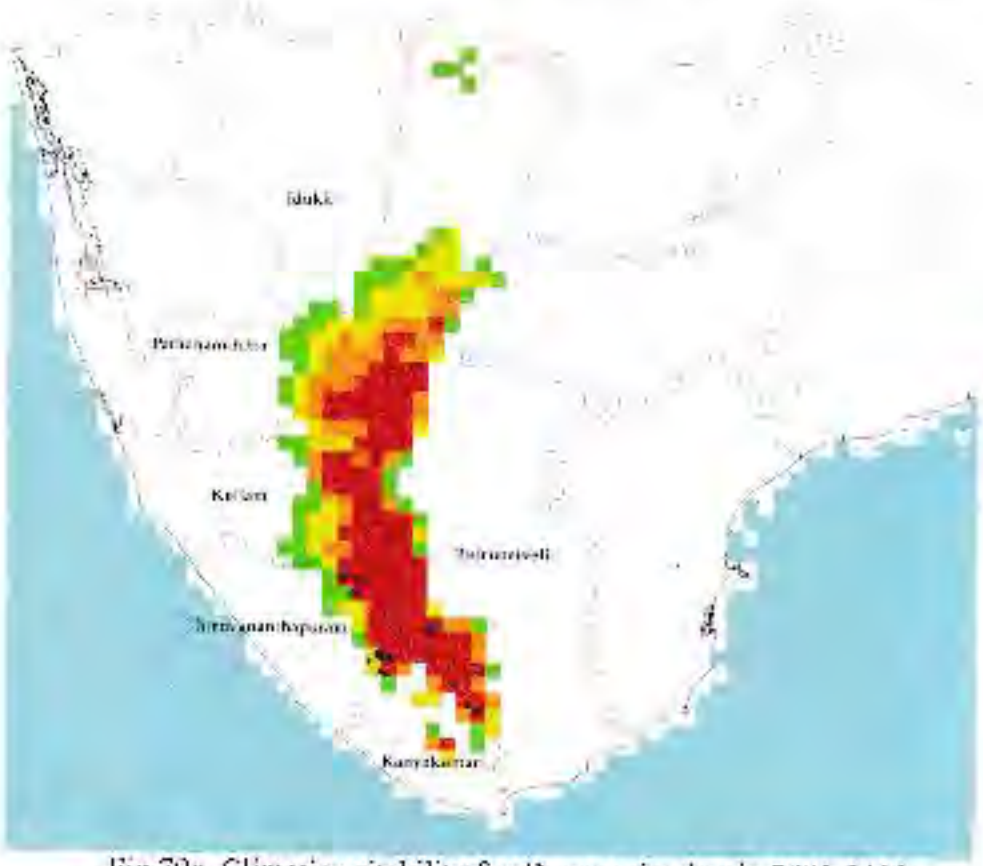

Fig 79a. Climatic suitability for *D. aravalpathra* in 2081-2100

3.2.4.3.9. Conservation action

No conservation action undertaken. Most of the present localities are in Neyyar WLS, Peppara WLS, Kalakkad-Mundanthurai Tiger reserve and protected reserve forests in Thiruvananthapuram and Kanyakumari Districts. Therefore, restoration program are not essential in this species for its survival. However, seed banking is required as a measure of *ex situ* conservation approach. This objective could not be fulfilled due to insufficient fund for satisfactory completion of the project. Large scale exploitation for commercial utilization should not be allowed as natural regeneration is very slow. In such application as any industrial use like the use as a substitute of vanillin-aroma (Verma and Sarkar 2014), propagation and cultivation is recommended.

3.2.4.4 Conclusions

This is a narrowly endemic medicinal plant used in folklore medicine reported as critically endangered. But IUCN so far did not evaluate the species. Based on our population study and published report we evaluated following IUCN Guidelines version 3.1 and concluded that it can't qualify for inclusion under critically endangered and endangered either. However, considering the slow regeneration and localized distribution it may be considered under **vulnerable** category. Out of the 24 location known based on our investigation and published reports we mapped 9 locations and estimated the population and projected a total of 22,068 mature individuals and 6,803 saplings. Other 5 locations in Kerala region also hold significant number of mature individuals. Significant population decline seems occurred in Sarkarmotta but other populations are intact except isolated attacks from wild boar. As most of the populations are in sanctuaries and protected forests, restoration appeared not essential and thus did not attempt for it. Modeling study revealed the presence of suitable habitats extending from Kanyakumari District in Tamil Nadu to hill ranges around Aryankavu gap in Kollam district of Kerala. Precipitation seasonality appeared as the most decisive factor for its survival and existence. At least a marginal precipitation throughout the year is essential for the survival of the species.

3.2.5 *Humboldtia unijuga* Beddome var. *trijuga* Joseph & Chandras.

The genus *Humboldtia* with seven species and 2 varieties is confined to southern Western Ghats except *Humboldtia laurifolia* extending to Sri Lanka (Balan *et al.*, 2016). IUCN enlisted *H. unijuga* var. *trijuga*, a critically endangered tree species because of its very restricted distribution, so far known only from the particular type locality of Agasthyamala ranges. The presence of three pairs of leaflets (rarely 2 or 4 pairs) and five staminodes makes *H. unijuga* var. *trijuga* differs from *H. unijuga* Beddome var. unijuga (Sanjappa, 1986).

In this background, the present study conducted to understand about the population, distribution and regeneration status of *Humboldtia unijuga* Beddome var. *trijuga* Joseph & Chandras (Table 27; Fig 7).

Table 27. Details of *Humboldtia unijuga* Beddome var. *trijuga* Joseph & Chandras.

Family	:	Fabaceae
Habit	:	Tree
Habitat & Ecology	:	Small tree of sub-montane evergreen forest
IUCN Red list category	:	Critically Endangered
Flowering & Fruiting	:	October to February
Distribution	:	Strictly endemic to the Agasthyamala ranges of Western Ghats

3.2.5.1 Materials and Methods

Study area

H. unijuga var. *trijuga* were located from the Chemungi hills close to Bonaccord tea estate (Fig 80, 81). The species is present in Chemmunji hills of Peppara wildlife sanctuary of Agasthyamala range.

Fig 80. Location map of Study area

Fig 81. Location of study area of *H. unijuga* var trijuga in Chemmunji hills (Google earth view)

Sampling method

To understand the population structure and ecological status of both species an elaborate study was carried out. A Quadrat of size 20 × 20 m area was chosen for the population study of the species (Fig. 82); within these quadrats all the trees with a girth ≥ 30 cm were identified and girth above 1.30 m measured.

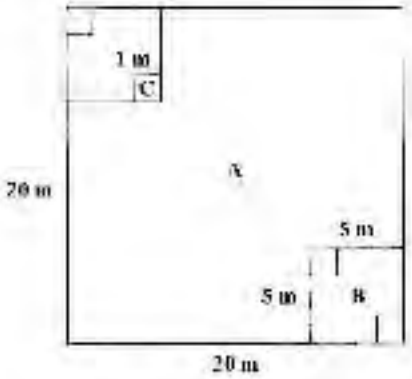

Fig 82. Quadrat for sampling vegetation: A-Trees (20 × 20 m), B-Shrubs (5×5 m); C-Herbs (1 × 1 m)

Two sub-quadrats with 5 × 5 m area were placed diagonally to study the ground layer of shrubs having height greater than 1 m and less than 30 cm girth, these include tree saplings and shrubs. Finally inside each shrub layer quadrats two sub-quadrats of size 1 × 1 m were placed diagonally for the detailed herb layer study. The herb layer includes herbs, tree seedlings as well as young ones of climbers and lianas. Presently three quadrats were laid in

the study area and a permanent plot of 20 × 20 m area is maintaining for understanding the growth pattern of candidate species

3.2.5.2 Observations

The current ecological investigation carried out in Chemungi hills of Bonaccord tea estate. This particular type locality falls into a submontane evergreen forest and usually such forest formation had lesser species diversity and basal area compared to lowland evergreen forests of Western Ghats. But these forests are the treasure trove of endangered species which cannot be seen from other forest formations. *H. unijuga* var. *trijuga* are such kind of species with narrow range of distribution. environmental stress or natural disaster can leads to the extinction of these species from the earth.

3.2.5.2.1 Species heterogeneity

Presently we laid three quadrats in Chemungi hills to study *H. unijuga* . var. *trijuga* populations. It covers an area of 1200 m². Altogether 21 associated tree species were documented from the three quadrats. Study area was dominated by *H. unijuga* var. *trijuga*, *Garcinia imberti*, *Agrostistachys meebaldii*, *Cullenia exarillata*, *Myristica beddomei*, *Hopea parviflora* etc. *H. unijuga* var. *trijuga* and *Garcenia imberti* another candidate species were present in the same type locality, but occurrence of *H. unijuga* depends on the altitudinal gradient. At the time of field study we have noticed the occurrence of *H. unijuga* var. *trijuga* starts from an altitude of 900 m and absent beyond 1100 m.

The species diversity measurement was done by Shannon index (H'). Simpson index was used for dominance and for evenness Pielou index was used. As far as tree layer is concerned Shannon index of diversity in Chemunji hill was 2.81 which is fairly good and almost resemblance to evergreen forest of Western Ghats. Species dominance and evenness are inversely proportional which determine the species distribution in ecosystem. The value of both the parameters lies between 0-1. Most of the species were evenly distributed in Chemunji hills with an evenness value of 0.88 and dominance of 0.08. The values for shrub and herb layer were calculated as Shannon index is 2.589. Simpson index is 0.112 and Pielou index is 0.850. These values are close to those of tree layer and thus demonstrate that both trees and shrubs are evenly distributed in Cheramunji hills.

3.2.5.2.2 Importance value index (IVI)

The ecological success of a species in an ecosystem is estimated by Importance Value Index (IVI). It is the product of three ecological parameters such as relative density, relative frequency and relative basal area and this gives a clear picture about the dominant or well established species of the ecosystem. In our study area among all species *Humboldtia unijuga* var. *unijuga* had the highest IVI of 35.09 for tree layer (Table 28). It is represented by mature

Fig 83. Mature tree of biggest (a) and smallest (b) range observed at Chemmunji, c. A flowering twig

trees of GBH 30-92cm with average 38cm (Fig 83). There are also small trees not reached reproductive maturity and thus included in the shrub layer (Fig 84). The shrub layer also showed high value (61.91) of IVI (Table 29) indicating high representation of lower growth class (Fig 84, 85a,b) and is dominant compared to other species. The herb layer is also evenly distributed with good representation of candidate **species** (Table 30; Fig 85c,d)). Thus it is clear that the candidate species is dominant with regard to different categories of the species in its distributed area.

Fig 84. Trees of small girth class not reached reproductive maturity

Table 28. Tree layer of *H. unijuga* var trijuja in the quadrats (20x20m) subjected to population analysis

Sl. No	Quadrate 1-3 (1200sqm)						
	Botanical name	No. of individuals	Frequency	Girth range (cm)	Relative density	Relative Frequency	IVI
1	*Agrostistachys meebaldii*	7	3	43	8.75	6.818	19.25
2	*Callenia exarillata*	1	1	57	1.25	2.273	5.81
3	*Diospyrous buxifolia*	2	1	70	2.5	2.273	6.87
4	*Entada rheedii*	2	1	54	2.5	2.273	6.46
5	*Garcenia imberti*	7	2	62	8.75	4.545	21.51
6	*Hopea pryiflora*	3	2	52	3.75	4.545	10.72
7	*H. unijuga vr trijuga*	16	3	50	20	6.818	35.09
8	*Memecylo gracile*	1	1	114	1.25	2.273	3.80
9	*Myristica beddomei*	4	3	102	5	6.818	16.31
10	Unidentified 18	1	1	89	1.25	2.273	5.85
11	Unidentified 13	1	1	32	1.25	2.273	4.09
12	Unidentified 1	3	3	66	3.75	6.818	13.31
13	Unidentified 10	1	1	65	1.25	2.273	3.86
14	Unidentified 11	1	1	63	1.25	2.273	10.78
15	Unidentified 12	1	1	87	1.25	2.273	5.08
16	Unidentified 2	8	3	81	10	6.818	34.82
17	Unidentified 3	3	3	100	3.75	6.818	15.53
18	Unidentified 4	6	1	54	7.5	4.545	15.53

19	Unidentified 5	2	2	74	2.5	4.545	8.51
20	Unidentified 6	2	2	95	2.5	4.545	12.45
21	Unidentified 7	2	2	88	2.5	4.545	14.97
22	Unidentified 8	2	2	66	2.5	4.545	11.79
23	Unidentified 9	2	2	41	2.5	4.545	11.78

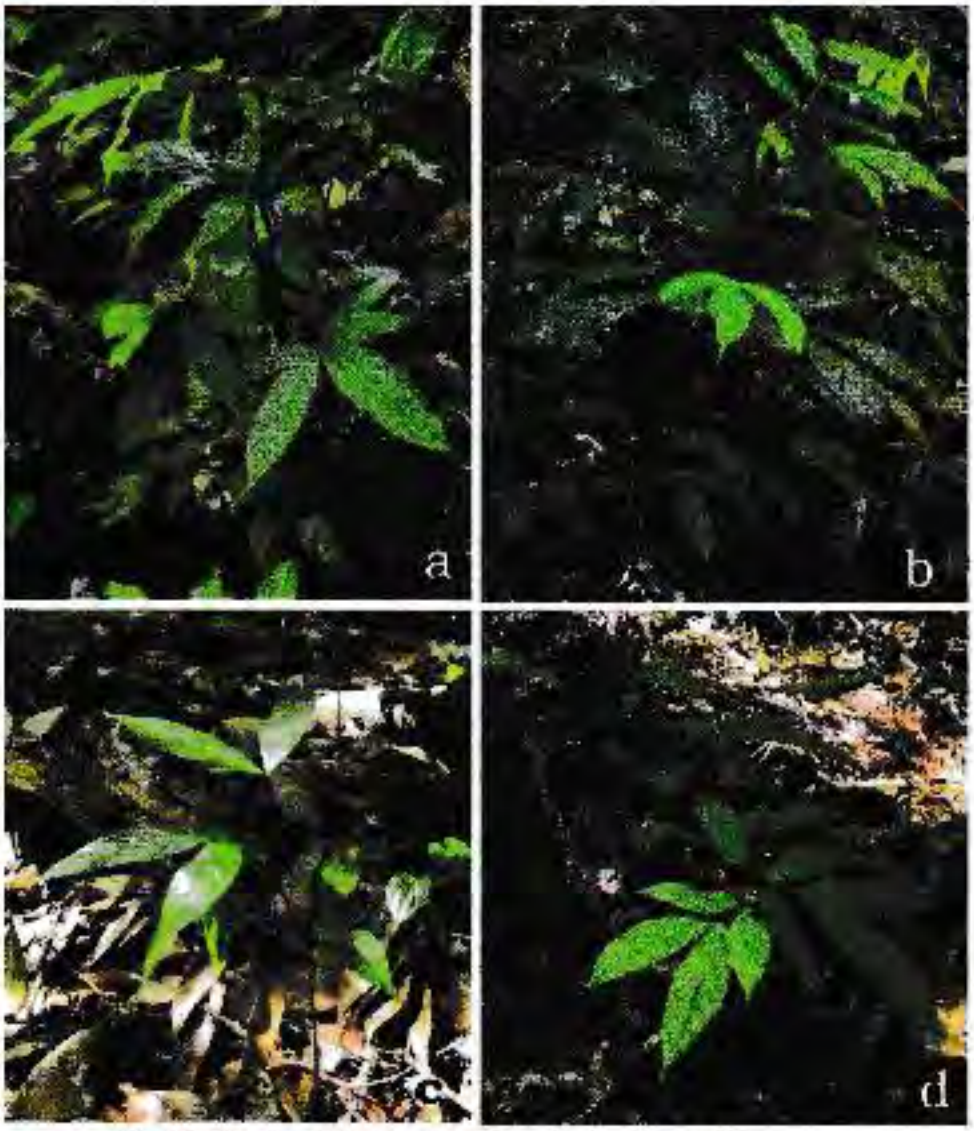

Fig 85. Shrub and herb stages of *H. unijuga* var. *trijuga*

Table 29. Sarub layer of *H. unijuga* var trijuga (5 × 5 m), height greater than 1 m and less than 30 cm girth

Quadrate 3x2 (150sqm)						
Sl. No	Botanical name	No. of individuals	Frequency	Girth range (cm)	Height range (cm)	IVI
1	*Agrostistachys borneensis* Becc.	32	6	7-15	400-500	54.11

2	*Antistrophe glabra* Pandur. & V.J. Nair	1	1	15	300	7.29
3	*Cinnamomum filipedicellatum* Kosterm	1	1	25	400	15.13
4	*Cinnamomum sulphuratum* Nees	1	1	6	400	3.6
5	*Dimorphocalyx beddomei* (Benth.	4	2	4-5	200-400	8.38
6	*Eryeibe paniculata* Roxb	1	1	25	400	6.21
7	*Garcinia imberti* Bourd	10	5	15	400	27.78
8	*Garcinia rubro-echinata* Kosterm	2	2	8	200	8.29
9	*Gluta travancorica* Bedd	1	1	15	300	7.29
10	*Goniothalamus wightii* Hook f Thoms	2	2	8-10	200	19.33
11	*Humboldtia unijuga* var *trijuga* Joseph & Chandras.	39	8	4-10	300-500	61.91
12	*Lasianthus acuminatus* Wight	3	2	15	300	10.99
13	*Memecylon gracile* Bedd	9	5	5-7	200	24.43
14	*Neolitsea cassia* (L.) Kosterm	2	2	4	300	6.39
15	*Pimenga dicksonii* (Roxb.) Blume	2	2	4	200	6.39
16	*Psychotria anamalayana* Bedd.	3	1	7-8	400	7.97
17	*Suprosma corymbosum* (Bedd.) Bedd.	1	1	10	200	4.86
18	*Semecarpus travancorica* Bedd	1	1	5	500	3.38
19	*Syzygium gardneri* Thw.	1	1	5	50	4.52
20	*Syzygium munronii* (Wight) Chandrab.	1	1	10	300	4.86
21	*Tabernaemontana gamblei* Subram	2	3	4-7	300-400	8.55
22	*Calamus brandisii*	8	3			
23	*Cinnamomum malabatrum*	8	3			
24	*Cullenia exarillata*	1	1			
25	*D. bucifolius*	5	2			
26	*Garcinia morella*	1	1			
27	*Gomphandra tetrandra*	2	1			
28	*Hopea parviflora*	4	2			
29	*Ixora sp*	3	2			
30	*Mallotus philippiense*	3	2			
31	*Nothopegia colebrukiana*	1	1			
32-40	Un identified	18	8			

Table 30. Herb layer of *H. unijuga* in the quadrates subjected to population analysis

Sl. No	Quadrates 3x2x4 (24sqm)			
	Species	Number of individuals	Frequency	Height range
1	*Aglaia sp*	5	3	
2	*Agrostistachys borneensis* Becc	1	1	
3	*Ancistrocladis heyneana*	5	1	
4	*Bischofia javanica* Blume	1	1	
5	*Calamus brandisii* Becc	10	8	
6	*Carvota urens*	1	2	
7	*Cinnamomum malabatrum*	2	2	
8	*Didymocarpus repens* Bedd.,	1	1	
9	*Dyasporus buxifolia*	3	3	
10	*Entada rheedii*	1	1	
11	*Garcenia sp*	1	1	
12	*Garcinia imberti* Bourd.	3	3	
13	*Garcinia rubro-echinata* Kosterm.	1	1	
14	*Glata travancorica* Bedd.	1	1	
15	*Hopea parviflora*	1	1	
16	*Humboldtia unijuga* var *trijuga*	26	13	27-52
17	*Lasianthus acuminatus* Wight,	1	1	
18	*Mallotus philippensis* (Lam.) Muell.-Arg.	4	3	
19	*Memecylon gracile* Bedd	5	3	
20	*Molineria trichocarpa* (Wight) Balakr.,	1	1	
21	*Nothopegia foetida*	1	1	
22	*Palaquium ellipticum* (Dalz.) Baill.	2	2	
23	*Pandanus foetidus* Roxb.	3	3	
24	*Pellionia heyneana* Wedd.	2	2	
25	*Peperomia blanda* (Jacq.) Kunth			
26	*Piper sp*	3	3	
27	*Pteris* sp.	7	3	
28	*Sauerila tinnevelliensis* C.E.C. Fisch	1	1	
29	*Syzygium mundagam*	1	1	
30	*Thottea barberi* (Gamble) Ding Hou	1	1	
31	*Zingiber sp*	2	2	

Fig. Herbaceous (a, b) and shrub layers (c, d) of *H. unijuga* at Chemmunji hills

3.2.5.2.3 Basal area and girth class

Trees are the basic elements of forest. Trees having GBH greater than ≥ 30 cm were considered for basal area and girth class analysis. GBH classes in cm considered for the analysis are 30 to 59, 60 to 89, 90 to 119, 120 to 149, 150 to 179 and 180 to 209 respectively. Chemungi hill had a basal area of 22.62 m²/h. the overall girth class distribution pattern of study area shows a reverse 'J' shaped curve, indicative of normal regeneration status (Fig 86).

Trees were distributed in all the girth class but the numbers of higher girth class trees were very less in Chemungi. But the presence of high number of trees in lower girth classes indicates good regeneration status in Chemungi, especially in 30 to 59 and 60 to 89 cm girth classes. Significant numbers of new recruits and different growth stages of *H. unijuga* (Figs 83-85) could be noticed in Chemmunji.

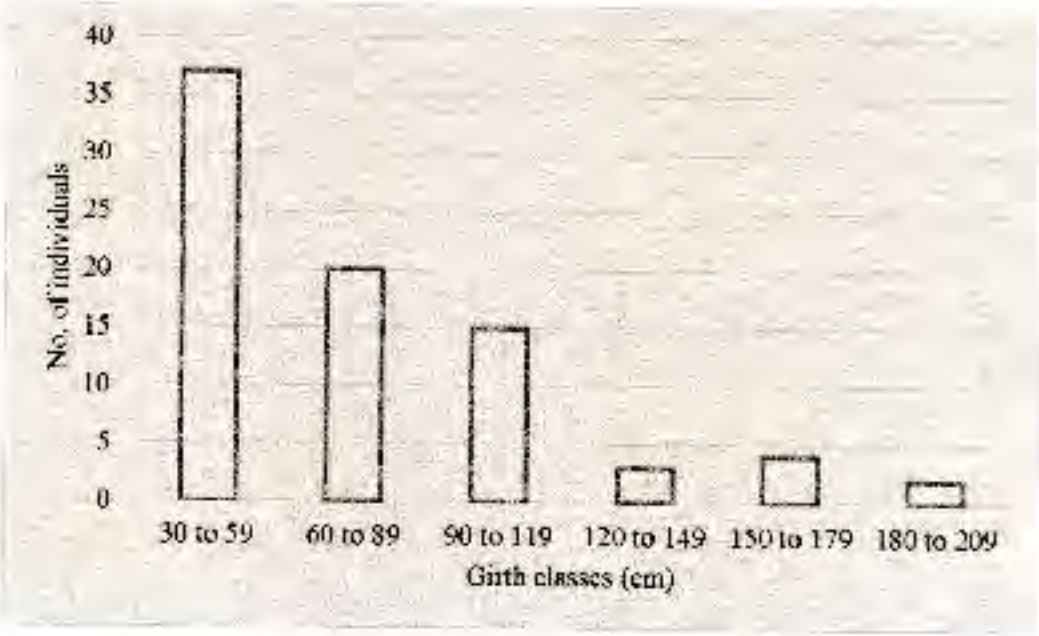

Fig 86. Girth class distribution of trees in Chemungi hills

3.2.5.2.4 Population threat

There is no pronounced threat to the population of *H. unijuga var. trijuga*. The locality of the species is exclusively within Peppara Wildlife sanctuary and there is no indication of exploitation or collection for ornamental, medicinal or any other purpose. Besides, there is high regeneration status in this species. However, it has a distribution in a single locality in a perimeter of about 2.57 Km with 1,67,984sqm area. A projected population of the species is summarized below.

Total plant distributed area = Extent of distribution:	167984sqm
Total sampled area:	1200sqm
Total mature trees:	16
Total represented as shrubs:	39
Total represented as herbs:	26

Population trend: Increasing

3.2.5.2.5 Projected Population in the plant distributed area
Total projected numbers of mature trees: 2,239

3.2.5.3 Status as per IUCN 1998 (World Conservation Monitoring Centre 1998)
Assessment Information
Red List Category & Criteria: **Critically Endangered B1+2c** ver 2.3
Year Published: 1998
Date Assessed: January 1, 1998

Geographic Range
Range Description: Occurring in the Travancore range.
Country Occurrence:
Native: India (Kerala)

Population
Known only from the type collection dating to the 19th century.

Habitat and Ecology
A small tree of submontane evergreen forest.
Systems: Terrestrial

3.2.5.4 Assessment of present threat status based on IUCN Guidelines (Annexure-1)

At present the species is treated as critically endangered. A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E (Annexure 1) and it is therefore considered to be facing an extremely high risk of extinction in the wild:

Present assessment information

Critically Endangered

- No population reduction due to any of the factors observed in the location subjected to detailed study during 2016 to 2019. No population reduction anticipated in the next 10 years as the locations with sufficient distributions is in protected forest and significant numbers of new recruits also present. Thus does not satisfy the criteria A for CR.
- Extent of occurrence is less than 100Km^2 ; Population identified in one locality only in a perimeter of 2.57Km. However, the population is continuous in the occurrence location. No continuing decline and extreme fluctuations. Thus the candidate species does not satisfy the criteria B for CR.
- Population size more than 250 mature individuals. No continuing decline to the level of 25%. The visited populations have more than 50 mature individuals. Fluctuation in number of mature individual is not noticed. Hence, does not satisfy the Criteria C.
- Quantitative analysis not undertaken but there is less than 50% probability of extinction in the wild within 10-20years based on our observations since 2016 unless any natural disasters come into force to destroy the habitat completely.

Endangered

- The species show high regeneration as mature trees of lower girth class is dominant. Only one tree recorded to have 92cm GBH. Average is only 52 as most of the trees are at 30-40 GBH. Even if population decline occurred due to habitat destruction, mainly the establishment of tea plantation during British rule period, the present distribution area is least influenced by anthropogenic pressures and showing the trend of population enhancement and spread.
- Population size estimated to less than 2,500 mature individuals. Population decline possible in the past due to habitat destruction ie., forest area cleared for tea estate. All the mature individuals were in a single population. No extreme fluctuation in number of mature individuals and decline of survived population noticed.
- Conclusion: partially meet criteria C, thus may be considered under Endangered Category **C2aii**.

3.2.5.5 Conservation action

The distributed area of the species belongs to Peppara Wildlife sanctuary. There is no indication of exploitation of this species for any use and the population is showing increasing and spreading tendency. Thus, restoration efforts are not recommended at present. If commercial exploitation comes into force, alternate source has to be established.

3.2.5.6 Conclusion

This species is assessed as critically endangered by IUCN. However, our study revealed good regeneration and spread of the species. Also, the ecological study facilitated to project a total of over 2000 mature individuals in a perimeter of 2.57Km in a single locality at Chemmunji. But, considering the distribution in a small area the status is evaluated as endangered. As the location is intact, population enhancement observed in the locality, presence of all life forms and high percentage of plants in the low girth class we concluded that the species is showing high regeneration. Also the locality belongs to a sanctuary.

3.2.6 *Garcenia imberti* Bourd

3.2.6.1 Description

Garcinia imberti Bourd. is an endangered tree species endemic to the southern Western Ghats (World Conservation Monitoring Centre,1998). Their populations are highly fragmented due to habitat degradation and disturbances together with poor recruitment (Gopalan and Henry 2000, Manikantan 2016, Manikandan and Ramasubbu 2017). It belongs to the Clusiaceae family and is confined to the valleys and river courses in specific pockets of submontane evergreen forests in Agasthyamala Biosphere Reserve (ABR) (08°39'0"N, 77°13'0"E). They are distributed to an altitudinal range of 900–1200 m. This dioecious species reaches a height of 30–40 feet occupying sub-canopy area (Mohanan et al 1997). The wood is yellowish grey and hard. The bark is brownish white and smooth. Leaves are simple, opposite with elliptic or lanceolate lamina. The major tree associates in the study sites include *Agrostistachys hermaneis, Cullenia exarillata, Cinnamomum sulphuratum, C. chemmunjiyanum, Elaeocarpus tuberculatus, G. travancorica, G. rubro-echinata, Humboldtia unijuga, Myristica dactyloides, Litsea laevigata, Palaquium ellipticum, Popowia sp., Vateria indica*, etc. The male and female trees are distributed in the ratio 1 : 1.2 respectively. Male flowers are smaller than female flowers. Flowering occurs annually and extends from February to May. Fruits have characteristic beak with thin rind and pulp normally bearing one or two seeds. Fruits matured during the months of August–October. Seeds are recalcitrant and exhibit hypogeal 'Garcinia type' of germination. In the natural habitat, seeds are dormant for more than six months and removal of seed coat alleviates dormancy (Anto *et al* 2018). Populations of G. imberti have been reported in three locations in ABR: Bonacaud (943 m amsl, 8°45'25"N, 77°11'20"E), Chemunji (1186 m amsl, 8°41'28"N, 77°11'04.8"E) and Ponmudi (1003 m amsl, 8°45'50.2"N, 77°06'48.5"E) (Anto *et al* 2018). The same authors again reported 2 more localities, ie, Sankhili in Thiruvananthapuram Forest Division, Kerala and Poonkulam in KMTR of Tamil Nadu (Anto and Anilkumar 2019, Anto et al 2020). Therefore, the known distribution of *G. imberti* extend from Poonkulam in Mundanthurai Tiger Reserve to Chemmunji hills in Peppara WLS, Ponmudi and Sankhili in Reserve forests of Thiruvananthpuram Forest Division very close to Shendurney WLS (Fig 37). These are occupied by evergreen forests without interruption/ human inhabitation.

As per IUCN categorization, it is an endangered species based on criteria B1I2c.

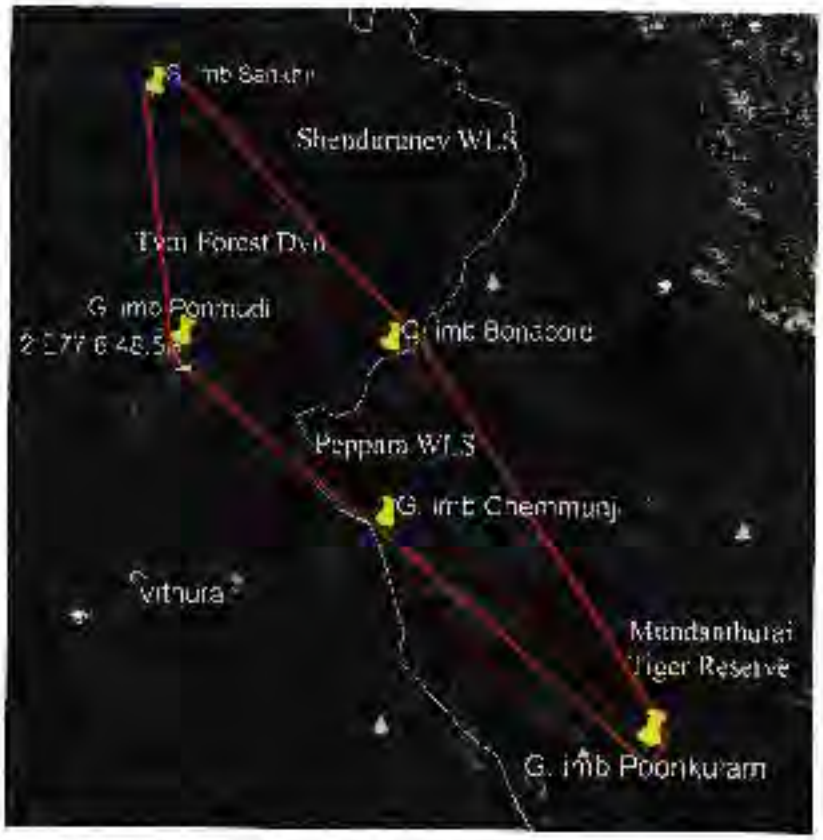

Fig.87. Distribution of *G. inberti* as per previous reports and confirmed in the present study

3.2.6.2 Population analysis

As that of *H. unijuga*, the species diversity measurement was done by Shannon index (H'), Simpson index for dominance and Pielou index for evenness. The tree layer of 20m x 20m quadrates of *G. inbertii* distribution in Chemungi hill showed Shannon index value 2.066 which is fairly good and almost resemblance to evergreen forest of Western Ghats. Species dominance and evenness are inversely proportional which determine the species distribution in ecosystem. The value of both the parameters lies between 0-1. Most of the species were evenly distributed in Chemungi hills with an evenness value of 0.8314 and dominance of 0.1929. The shrub layer of 5x5m quadrates showed Shannon index value 2.459, evenness value 0.8869 and dominance value 0.1225. The values of tree layer and shrub layers are very near and thus demonstrate that both trees and shrubs are evenly distributed in Chemmunji hills.

The ecological success of a species in an ecosystem is estimated by Importance Value Index (IVI. In our study area, among all species *G. inbertii* had the highest IVI of 68.07 and 41.0 in the tree and shrub layer respectively (Table 31, 32) revealing that the candidate species is dominant with regard to tree and shrub of the species classes (Fig 88) in its

distributed area. The herb layer (Fig 88) is also evenly distributed with good representation of candidate species (Table 33).

Table 31. Characters of tree layer of *G. imberti* in 20x20sqm

Sl. No	Botanical name	No. of individuals	Girth range (cm)	Height range (cm)	IVI
1	*Agrostistachys borneensis* Becc	3	68-85	150-190	21.35
2	*Cinnamomum sulphuratum* Nees	2	55-178	20-22	24.28
3	*Elaeocarpus serratus* L. var. *weibelii* Zmarzty	1	137	220	16.43
4	*Garcinia imberti* Bourd	13	50-116	130-200	66.5
5	*Gluta travancorica* Bedd.	2	91	220	18.51
6	*Litsea* sp	1	51	130	11.3
7	*Mesua ferrea* L.	1	118	210	14.89
8	*Palaquium ellipticum* (Dalz.) Baill.	3	68-233	150-200	47.03
9	*Semicarpus travancoricum* Bedd.	1	68	200	11.94
10	*Syzygium gardneri* Thw	1	86	170	18.17
11	Syzygium *mythendrae* (Bedd. ex Brandis) Gamble.	2	86-116	170-210	26.93
12	*Xanthophyllum arnottianum* Wight	2	52	140-150	22.66

Table 32. Characters of shrub layer of *G. imberti*. 5 × 5 m, height greater than 1 m and less than 30 cm girth

Sl. No	Botanical name	No. of individuals	Girth range (cm)	Height range (cm)	IVI
1	*Actinodaphne bourdillonii* Gamble.	1	18	400	19.21
2	*Agrostistachys borneensis* Becc.	2	10-12	500	14.64
3	*Cinnamomum sulphuratum* Nees	1	5	300	10.32
4	*Dimorphocalyx beddomei* (Benth.	2	4-5	200-400	14.18
5	*Garcinia imberti* Bourd	6	5-8	400	41.00
6	*Goniothalamus wightii* Hook. f. & Thoms.	1	10	200	12.20
7	*Memecylon gracile* Bedd.	2	10-12	400	29.05
8	*Neolitsea cassia* (L.) Kosterm	1	4	300	10.01
9	*Palaquium ellipticum* (Dalz.) Baill.	2	7-12	150-500	17.96
10	*Psychotria flavida* talbot	1	15	300	15.30
11	*Semicarpus travancoricum* Bedd.	1	8	200	25.28

12	*Syzygium gardneri* Thw.	2	15-20	500	22.87
13	*Syzygium munronii* (Wight) Chandrab.	2	23	300	15.30
14	Syzygium *myhendrae* (Bedd. ex Brandis) Gamble.	1	15	500	11.29
15	*Tabernaemontana gamblei* Subram. & Henry.	1	20	500	19.65
16	*Xanthophyllum arnottianum* Wight	1	22	500	21.74

Fig 85. *Garcenia imberii* at Chemmunji hills. (a) Tree population. (b) Shrub stage. (c) herb stage

Table 33. Herb layer of *G. imberii* populations

Sl. No	Species	Representation in Quadrats
1	*Acrotrema agasthyamalayana* Wight.	2
2	*Calamus brandisii* Becc.	2
3	*Cinnamomum filipedicilatum* Kosterm.	2
4	*Cinnamomum sulphuratum* Nees	2
5	*Derris benthamiana* (Thw) Thw.	2
6	*Garcinia imberii* Bourd.	2 10 Nos; 14-60cm

7	*Gompiandra coriacea* Wight.	2
8	*Litsea nigrescens* Gamble.	2
9	*Memecylon gracile* Bedd.	2
10	*Mesua ferrea* L.	2
11	*Ophiorhiza erianta* Wight.	2
12	*Poecilomeuron indica* Bedd.	2
13	*Popowi beddomeana* hook f.&Thoms	2
14	*Setogineila* sp.	2
15	*Smilax zeylanica* L.	2
16	*Syzygium gardneri* Thw.	2
17	Syzygium *myhendrae* (Bedd. ex Brandis) Gamble	2
18	*Thottea barberi* (Gamble) Ding Hou.	2

3.2.6.2.1 Basal area and girth class

Trees are the basic elements of forest. Trees having GBH greater than > 30 cm were considered for basal area and girth class analysis. GBH classes in cm considered for the analysis are 5cm-203cm. Chemungi hill had a basal area of 12.3 m^2/h. The overall girth class distribution pattern of study area shows that most of the population of *G. imbertii* is at girth range 40-99cm (Fig 89). However, low girth range (20-40) is negligible in the studied quarter. Therefore the regeneration observed seems to be not normal even though shrub stage of 5-20 cm is represented in significant numbers.

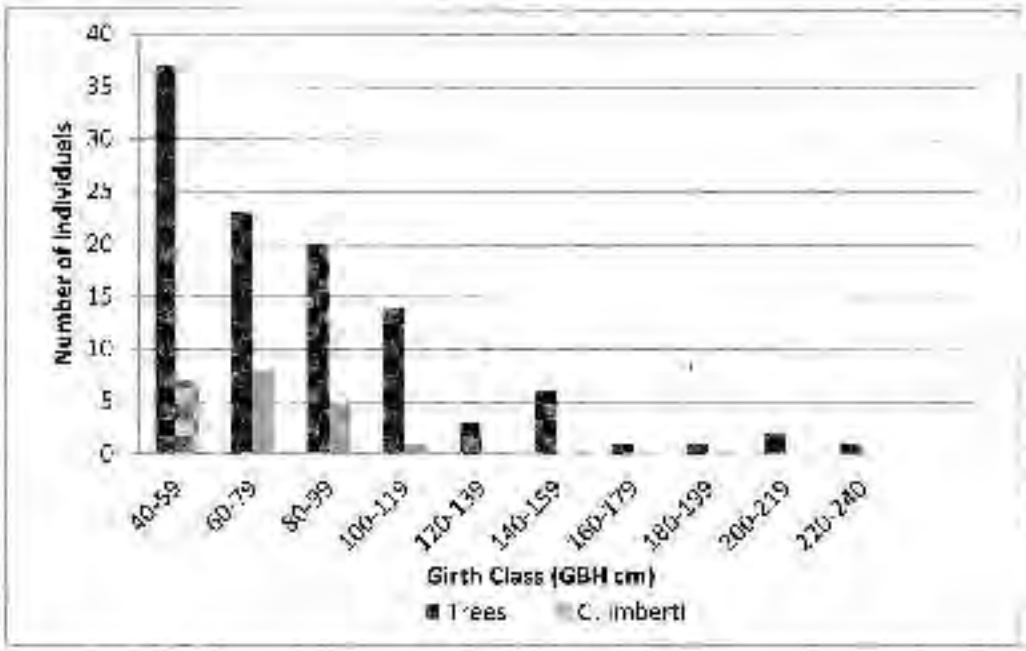

Fig 89. Girth class distribution of trees in *G. imbertii* distribution area in Chemungi hills

In general, trees were distributed in all the girth class but the numbers of higher girth class trees were very less in Chemungi. But the presence of high number of trees in lower girth classes indicates good regeneration status in Chemungi, especially in 40 to 59 and 60 to 89 cm girth classes.

3.2.6.2.2 Population threat

The locality of the species under study at Chemmunji is within Peppara Wildlife sanctuary and there is no indication of exploitation or collection for ornaments, medicinal or any other purpose. Besides, there is satisfactory regeneration status in this species. Moreover, it has known distribution to other localities as Bonacord in Peppara WLS, Sankhili and Ponmudi in reserve forests of Thiruvaananthapuram Forest Division and Poonkulam in Mundanthurai Tiger Reserve in a perimeter of about 72.26 Km with 172,109,358sqm area. All are protected forests not having any threat to the habitats. But some population loss may have occurred long back at Ponmudi and regeneration status is very poor in that locality. We did not study the population status in localities other than Chemmunji and thus actual population size cannot be projected. Nevertheless, based on the study conducted at Chemmunji, population has been projected for this locality.

3.2.6.2.3 Population estimation

Total plant distributed area= Extent of distribution:	172109358sqm=172Km^2
Studied area at Chemmunji:	162413sqm=0.16Km^2
Total sampled area:	1260sqm
Total mature trees:	14
Total represented as shrubs:	18 (in 25sqm)
Total represented as herbs:	10 (in 4sqm)

Projected Population of mature trees in the plant distributed area at Chemmunji

Total projected numbers of mature trees:	1,894 (in one location)

3.2.6.3 Status as per IUCN 1998 (World Conservation Monitoring Centre 1998)

Assessment Information

Red List Category & Criteria: Endangered B1+2c ver 2.3

Year Published: 1998

Date Assessed: January 1, 1998

Previously Published Red List Assessments

1998 Indeterminate (I)

Geographic Range

Range Description:

Known from the Agasiyamalai Hills.

Country Occurrence:

Native: India (Kerala)

Population

Collected only once.

Habitat and Ecology

The species occurs in submontane evergreen forest.

Systems: Terrestrial

Threats

Large areas have been exposed to fires, grazing, the establishment of commercial plantations and cutting for fuelwood.

Conservation Actions

Almost 1,000 km² of forest are now under protection within sanctuaries.

3.2.6.4 Assessment of Present Status based on IUCN Guidelines

A taxon is endangered when the best available evidence indicates that it meets any of the following A to E (Annexure-I) and it is therefore considered to be facing a very high risk of Extinction in the wild

- No population reduction observed in the locations subjected to detailed study during 2016 to 2019
- Extent of occurrence estimated is more than 100 km². But no continuing decline of extent of occurrence, area of occupancy observed or projected. No indication of reduction in number of locations and sub populations.
- No pronounced continuing decline of mature individuals or extreme fluctuations in extent and area of occupancy.
- Population size estimated to less than 2,500 (1894) mature individuals in one locality. Not known for other localities. Population decline possibly happened in the past due to habitat destruction ie., forest area cleared for tea estate at Ponmudi only. No extreme fluctuation in number of mature individuals and decline of survived population noticed/ possible in other localities. Population is continuous in the sub populations.
- Population size estimated more than 250 mature individuals.

- Thus it is not endangered based on criteria A-D
- Extent of occurrence estimated is less than 20,000 km2;
- Known to exist at less than 10 locations.
- Population with a very restricted area of occupancy (less than 20 km2) and number of locations (5)
- Conclusion: Vulnerable B1a; D2

3.2.6.5 Conclusions

The population is showing natural regeneration and increasing in numbers except at Ponmudi. All life forms are also noticed in the natural locality as Chemmunji. Thus this species is evaluated to consider under vulnerable category. All other locations are either in sanctuaries as KMTR, Peppara WLS or protected reserve forests. Besides, there is no exploitation for any use. Therefore, restoration efforts are not essential in this species.

3.2.7 *Agasthiyamalaia pauciflora* (Bedd.) S. Rajkumar & Janarth.

3.2.7.1 Description

Agasthiyamalaia pauciflora (Bedd.) S. Rajkumar & Janarth. (Table 34) is another important species of our concern. According to new assessment of IUCN red list category this species fall into the group of critically endangered species because of its narrow distribution. It is endemic to the southern Western Ghats collected from the Travancore and Thirunelveli regions during 1917. It was rediscovered in 1999 based on collections from Kalakkad-Mundanthurai Tiger reserve and Mahendragiri (Mohanan *et al*, 1999). Later it was collected from different localities as Vakkenragiri, Kannikkatti, Inchikkuzhi, Veyillar near Nagamalai, Ithu river bank, Sigappara bank, Chittar bank near Keeripparai all belongs to Kalakkad Mundanthurai Tiger Reserve during 1989-2002 (Rajkumar and Janarthanam 2007). As part of a species recovery project supported by DBT, Government India during 2006-2011, JNTBGRI and St. Xavier's College, Palayamkottai undertook surveys in Peppara Wildlife Sanctuary and Kalakkad- Mundanthurai Tiger Reserve and traced 6 populations in KMTR and one population in Iathimetta near Ponaccord in Peppara Wildlife sanctuary (JNTBGRI, 2011) at 600-950m altitudes.

Table 34. Details of *Agasthiyamalaia pauciflora*

Family	:	Clusiaceae
Synonym	:	*Poecilonewron pauciflorum* Bedd.
Habit	:	Tree
Habitat & Ecology	:	The species occurs in evergreen hill forest
IUCN Red list category	:	Critically endangered
Flowering & Fruiting	:	April to June
Distribution	:	Endemic to southern end of the Western Ghats

3.2.7.2 Population study

In the present study, we conducted preliminary surveys in Lathimotta (650m), near Bonaccord of Peppara WLS. The population possessed around 65 individuals with about 7 small to medium sized trees. The trees those observed at fruiting stages were small (Fig 90a) compared to larger (Fig. 90c) found in Veyillar near Inchikkuzhi of Kalakkad- Mundanthurai Tiger reserve. But significant numbers of seedlings/saplings of various stages could be observed in lathimotta (Fig.91, 92). In addition, small plants distributed on the way from Kramana river basin to Attayar, near to rivulets could also be identified.

Fig 90a-d. *A. pauciflora*, a. a small tree at lathimotta, b. a flushing twig, c. a flowering twig, d. a twig with fruits.

Fig 90e. A mature tree of highest girth class observed at Veliyar near Inchikkuzhi-Puonkulam in Nagamalai of KMTR on flushing. It was observed during a previous study by the PI.

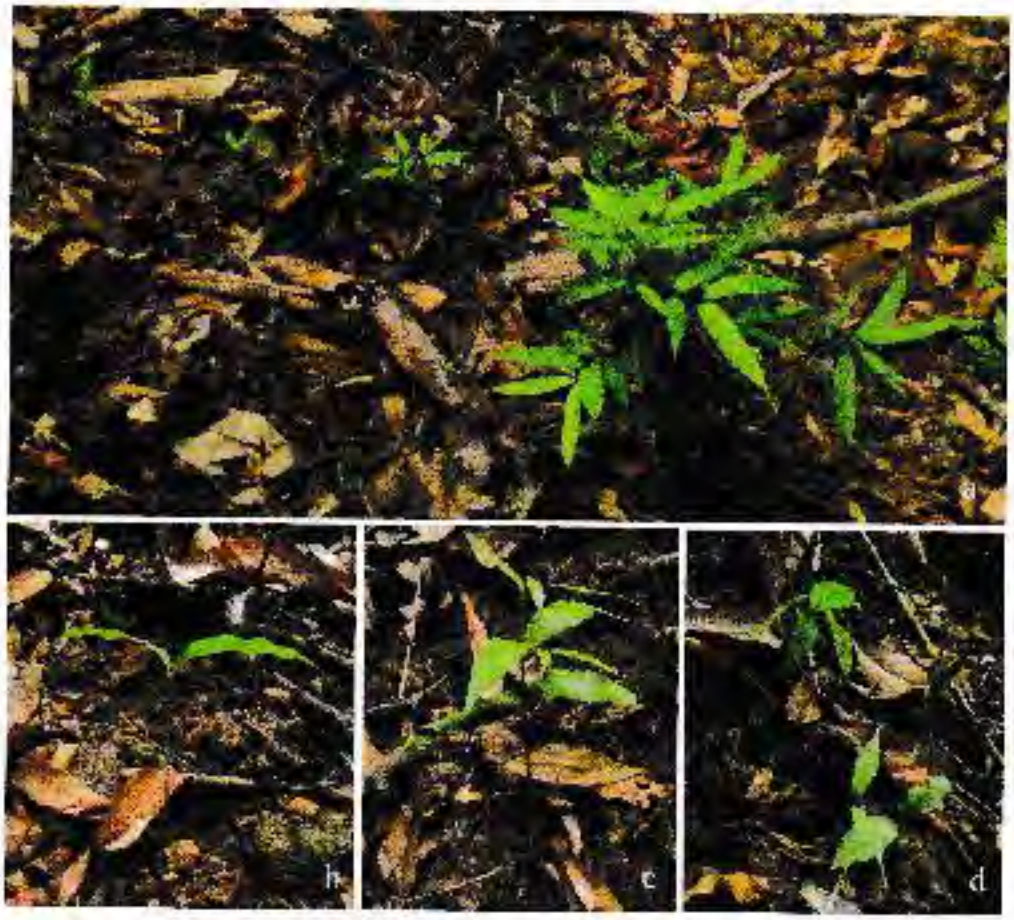

Fig 91a-d. New recruits of *A. paniculata* at seedling stages in its native habitat at Lathimotta of Peppara WLS

Fig 91e,f. New recruits of *A. pauciflora* at shrub stage of developemnt in its native habitat at Iathimotta of Peppara WLS

3.2.7.2.1 Vegetative phenology

Leaf initiation was observed in certain adult individuals during the month of February onwards. Leaf flushing began from February onwards and extended up to March alongwith matured leaves. Mass flushing of new leaves with dark brown lamina and green midrib later changed to pale brown followed by pale green and finally to dark green colour (Fig. 90,92).

Fig 92. Mass flushing in small trees of *A. pauciflora*

3.2.7.2.2 Ecological study

Ecological study for understanding the population status *A. pauciflora* was started in Lathimotta of Bonaccord hills, but could not be completed. The study was initiated with the completion of two quadrats. A total number of five individuals of candidate species with 2 mature ones were encountered from the two quadrats laid covering in an area of 800 m² in the total 6630sqm plant distributed area, in the sub-population. The size and sampling method was chosen same as the one used in *Humboldtia* and *Garcinia* population study.

3.2.7.2.3 Population status

A previous study made in 2009 (JNTBGRI 2011) reported 21species of GBH above 10cm and a total of 245 individuals in 1000sqm area. Among them *Cullenia exarillata* had highest IVI value of 24.1 and *Agathyamalaia pauciflora* stand at 5th position with IVI of 18.47. However, relative frquency and relative density of *A. pauciflora* was equal to that of *C. exarillata*. Study by the collaborative team from St. Xvier's College revealed average 20-25.7 mture individuals of *A. pauciflora* among 4 populations in Inchikkuzhi, Kannikkadi, Veyliyar and Mahendragiri with a total average 54.3 in 3600 sqm. They also reported 28 saplings and 70 seedlings in 400sqm area projecing a total of 54 mature individuals, 252 in the shrub layer and 630 in the herb layer. The mature individuals are medium sized trees and come to the second canopy in the distributed area. This report along with our observation in lathimotta with 7 mature individuals and 58 saplings/seedlings reveals satisfactory regeneration to self-sustain without any risk of extinction in future.. However, exact distribution area has not been determined and thus it is difficult to project the population size. Even though it is mostly distributed along the banks of rivulets, it shows a tendency to spread towards the interior forest. It is very much evident in the valley of Nagarulai in KMTR, on the way from Inchikkuzhi to Poonkulam. As it is not randomly distributed in the area of distribution, the boundaries of sub populations has to be determined to get a good estimate.

3.2.7.2.4 Distribution extent

Distribution of the species extends from Mahendragiri to Kannikkadi in Kalakkad-Mundanthurai and to Lathimotta near Bonaccord of Peppara WLS based on our study and published reports. The reported localities do not have GPS coordinates and thus a most probable locality along streams, at the specified altitude has been marked in google earth, the point joined to get extent of distribution. Accordingly, the species have minimum distribution

in 55Km perimeter and 189SqKm area (Fig 93). All the loction inside the area are continuous except a few tea estates in KMTR. Thus stream banks at 600-950m may have potential distribution of this species.

Fig 93. Extent of distribution of *A. pauciflora* in Peppra WLS and KMTR

3.2.7.2.5 Population threat

The species is riparian in distribution. Some area in KMTR in the hill tops cleared for Tea estate seems least influenced the *A. pauciflora* habitats. However, the distributed areas belong to sanctuaries and are well protected. At present there is no indication of exploitation of this species for timber or other purpose. Therefore, there is no indication of extreme fluctuation in the habitat and its populations at present.

3.2.7.3 Status as per IUCN evaluation 1998 (World Conservation Monitoring Centre 2017)

Assessment information

Red List Category & Criteria: Critically Endangered B1+2c ver 2.3

Year Published: 2017

Date Assessed: January 1, 1998

Annotations: Needs Updating

Geographic Range

Range Description:

This species was collected just two or three times in 19th century in Travancore and Tinnelveli.

Country Occurrence:

Native: India (Kerala, Tamil Nadu)

Population

It was once a useful timber. Recent botanical surveys have failed to locate any specimens. It is not known for certain whether the species is now extinct.

Habitat and Ecology

Evergreen hill forest.

Systems: Terrestrial

Threats

The habitat has been severely reduced in extent.

3.2.7.4 Assessment of Present Status based on IUCN Guidelines

Critically Endangered

- At present the species is treated as critically endangered. However recent collections from several populations, though from a small geographic region necessitates its reassessment. It was also pointed out by Rajkumar and Ivanthamam (2007). Therefore it has been re-evaluated based on IUCN guidelines version 3. (Annexure-I)

- No population reduction due to any of the factors observed in the location subjected to detailed as part of the present study during 2016 to 2019 and a previous study during 2007-2011. No population reduction anticipated in the next 10 years as the locations with sufficient distributions is in protected forest and significant numbers of new recruits also present. Thus does not satisfy the criteria A so consider as CR

- Extent of occurrence is more than 100Km^2 (189); Population identified in 7 localities in a perimeter of 55Km. The population more or less contiguous based on our observation in the Indri/Kuzhi-Poondi dam stretch. The sub-populations in Mahendragiri and Lathamotta are separated by about 25 and 10 Km. No continuing decline and extreme fluctuations. Thus the candidate species does not satisfy the criteria B so consider as CR.

- Population size more than 250 mature individuals. No continuing decline to the level of 25%. The visited populations at KMTR have more than 50 mature individuals. Fluctuation in number of mature individual is not noticed. Hence, does not satisfy the Criteria C so consider as CR.

- More than 50 mature individuals in the localities; not satisfy criteria D.

- Quantitative analysis not undertaken but there is less than 50% probability of extinction in the wild within 10-20years based on our observations since 2006.

- *Agasthyamalaia pauciflora* does not meet the criteria A-D to place under Critically Endangered Criteria. Also, the species show high regeneration as mature trees of lower girth class is dominant. Even if population decline occurred due to habitat destruction, mainly the establishment of tea plantation during British rule period, the present distribution area is least influenced by anthropogenic pressures and showing the trend of population enhancement and spread.

Endangered

- No population reduction observed in the locations subjected to detailed study to consider under endanagered category
- Extent of occurrence estimated is higher than 100 km^2 (189). No continuing decline of extent of occurrence, area of occupancy observed. No indication of reduction in number of locations and sub populations. No pronounced continuing decline of mature individuals or extreme fluctuations in extent and area of occupancy
- Population size possible to number more than 2,500 mature individuals (54 observed in 0.00360SqKm area: Minimum 0.22 SqKm area in the 189SqKm extent of distribution anticipated to have *A. pauciflora* distribution
- No population decline; no extreme fluctuation in number of mature individuals and decline of survived population noticed.
- *A. pauciflora* does not meet the criteria A, B, C and D to consider as endangered. Population viability analysis not undertaken to take decision on Category E. But, there is no possibility of extinction in the next 100years

Vulnerable

- Extent of occurrence estimated to be less than 20,000 km2, and known to exist at **less than 10 locations.**
- Population restricted in the form of population with a very restricted area of occupancy (less than 20 km2)
- **Conclusion: Vulnerable B1a; D2**

3.2.7.5 Conclusion

The presence localities are at sanctuaries, the distributed area is continuous, spread from river banks to interior forests observed, all life forms exists, trees of low girth class represented in higher numbers than high girth class, no exploitation for any purpose observed and thus no

special conservation action required. However, due to lower distribution extent and known to occur in less than 10 locations, it may fit in to vulnerable category.

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Annexure-I

THE CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE

CRITICALLY ENDANGERED (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

(a) direct observation

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of ≥80% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of ≥80%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥80% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 100 km2, and estimates indicating

a least two of a-c:

a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

2. Area of occupancy estimated to be less than 10 km2, and estimate indicating at least two of a-c:

a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

C. Population size estimated to number fewer than 250 mature individuals and either:

1. An estimated continuing decline of at least 25% within three years or one generation, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

a. Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 50 mature individuals.

OR

(ii) at least 90% of mature individuals in one subpopulation

b. Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 50 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years).

ENDANGERED (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

(a) direct observation

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of ≥50%, projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥50% over any 10 year or three generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 5,000 km2, and estimates indicating at least two of a-c:

a. Severely fragmented or known to exist at no more than five locations.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

2. Area of occupancy estimated to be less than 500 km2, and estimates indicating at least two of a-c:

a. Severely fragmented or known to exist at no more than five locations.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

C. Population size estimated to number fewer than 2,500 mature individuals and either:

1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

a. Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 250 mature individuals,

OR

(ii) at least 95% of mature individuals in one subpopulation.

b. Extreme fluctuations in number of mature individuals.

D. Population size estimated to number fewer than 250 mature individuals.

E. Quantitative analysis showing the probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).

VULNERABLE (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:

A. Reduction in population size based on any of the following:

1. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:

(a) direct observation

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

2. An observed, estimated, inferred or suspected population size reduction of >30% over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1.

3. A population size reduction of ≥30% projected or suspected to be met within the next 10 years or three generations, whichever is the longer (up to a maximum of 100 years), based on (and specifying) any of (b) to (e) under A1.

4. An observed, estimated, inferred, projected or suspected population size reduction of ≥30% over any 10 year or three generation period, whichever is longer (up to a maximum of 100

years in the future), where the time period must include both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of (a) to (e) under A1

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:

1. Extent of occurrence estimated to be less than 20,000 km2, and estimates indicating at least two of a-c:

a. Severely fragmented or known to exist at no more than 10 locations.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals

2. Area of occupancy estimated to be less than 2,000 km2, and estimates indicating at least two of a-c:

a. Severely fragmented or known to exist at no more than 10 locations.

b. Continuing decline, observed, inferred or projected, in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) area, extent and/or quality of habitat

(iv) number of locations or subpopulations

(v) number of mature individuals.

c. Extreme fluctuations in any of the following:

(i) extent of occurrence

(ii) area of occupancy

(iii) number of locations or subpopulations

(iv) number of mature individuals.

C. Population size estimated to number fewer than 10,000 mature individuals and either

1. An estimated continuing decline of at least 10% within 10 years or three generations, whichever is longer, (up to a maximum of 100 years in the future) OR

2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following (a-b):

a. Population structure in the form of one of the following:

(i) no subpopulation estimated to contain more than 1,000 mature individuals, OR

(ii) all mature individuals in one subpopulation.

b. Extreme fluctuations in number of mature individuals.

D. Population very small or restricted in the form of either of the following:

1. Population size estimated to number fewer than 1,000 mature individuals.

2. Population with a very restricted area of occupancy (typically less than 20 km2) or number of locations (typically five or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.

E. Quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years.

Budget utilization

A. Non-Recurring (e.g. equipments, accessories, etc.)

Item	Budget allocation	Fund received	Balance
Digital Camera	40,000	41950	(-) 1950
Binocular	40,000	4000	0.0
Total	80,000	81,950	(-) 1950

B. Recurring

B.1 Manpower

S. No	Position No.	Consolidated Emolument	Budget allocation	Fund received	Total Utilized	Balance
1	JRF-1	Initial 12,000/–10% +HRA Final 16,000 10% HRA	5,80,800	4,15,600	4,42,797	(-) 27,197
Total			5,80,800	4,15,600	4,42,797	(-) 27,197

B.2 Consumables

S. No	Item	Budget allocation	Fund received	Total Utilized	Balance
1	Chemicals	5,15,000	2,90,000	2,82,004	10,996
2	Glassware, Nursery and field collection materials				
Total		5,15,000	2,93,000	2,82,004	10,996

Other items

Other Items	Budget allocation	Fund received	Total Utilized	Balance
B.3 Travel	3,75,000	2,75,000	3,50,337	(-) 75,337
B.4 Contingency	2,11,200	1,56,400	1,63,205	(-) 6,805
B.5 Overhead Institutional charges	2,40,000	1,80,000	1,92,000	(-) 12,000
Grand Total	**20,00,000**	**14,00,000**	**15,12,293**	(-) **1,12,293***

***Exclude expenditure on Project report preparation and Audit fee**

Dr. S. William Deense
PI

Publications/Seminars

1. Akhil C. A. M. Rajendraprasad and S. William Decruse, GIS application for habitat mapping and distribution modelling of *Decalepis arayalpathra* (J. Joseph & V. Chandrasekaran) Venter: a critically endangered shrub, 'Second National seminar on Geospatial Information Systems: Emerging Trends and Utilities" Inter University Centre for Geospatial Information Science and Technology, 14th and 15th December 2017, Inter University Centre for Geoinformatics, University of Kerala.

2. Akhil CA and S. William Decruse, Conservation introduction and establishment of *Vanda wightii* Rchb.f at JNTBGRI. Current Trends in Conservation, Sustainable Development and Biological and Social benefits of Medicinally andfloriculturally Significant Orchids. National Conference of the The Orchid Society of India. RARS, KAU, Amblavyal. 16-18 March 2018.

Acknowledgements

Kerala State Biodiversity Board is acknowledged for financial support tdundertake this study.

Director, JNTBGRI is acknowledged for providing facilities to undertake the study.

We express our sincere gratitude to Principal Chief Conservator of Forest (Wildlife), Kerala State Forest Department, Government of Kerala for sanctioning permission to enter protected forest segments in Kerala and to restore the target species in selected locations.

We sincerely acknowledge the support provided by Wildlife Warden and Assistant Wildlife warden, Idukki Wildlife Sanctuary; DFO, Wayanad South Division; Wildlife Warden Peppara Wildlife Sanctuary; Wildlife Warden, Neyyar Wildlife Sanctuary; Section Forest Officer, Kozhukkanam, Idukki WLS; Section Forest Office, Klamala-1, Neyyar WLS; Section forest officer and other offiicals in Vithura and Kallar forest section to undertake field surveys and reinforce the target species. Members of Podiyan EDC, Kottathikkavu EDC and forest officials at Athirumalamala and Kozhukkanam forest office are acknowledged for their support during restoration and monitoring.

We express our sincere gratitude to Mr. Appicherakkan from Andoori, EDC members of Kunnathumala and Korikkuzhi in Neyyar Wildlife sanctuary, VSS members from Ponmudi and Kallar for their support during population study of Decalepis arayalpathra.

Help rendered by Dr. ES. Santhoshkumar and Dr. T. Shaju for identification of associates of target plants under study are gratefully acknowledged.

Co-ordinator (s), Finace controller (s), Smt. R. Sobha Sankar and other Staff of PCC, JNTBGRI are acknowledged for administrative support through out the project period.

Principal Investigator

KSCSTE-JAWAHARLAL NEHRU
TROPICAL BOTANIC GARDEN AND RESEARCH INSTITUTE
Palode, Thiruvananthapuram-695562, Kerala, India