KFRI Research Report No. 516 ISSN: 0970-8103

Conservation through restoration of wild nutmeg tree populations of Western Ghats of Kerala

P. A. Jose
P. K. Chandrasekhara Pillai

Kerala Forest Research Institute
Peechi 680 653
June 2016

KFRI Research Report No. 516 **ISSN: 0970-8103**

Conservation through restoration of wild nutmeg tree populations of Western Ghats of Kerala

P.A. Jose
P.K. Chandrasekhara Pillai

Kerala Forest Research Institute

Peechi, Thrissur-680 653

June 2016

PROJECT PARTICULARS

1.	Title of the project	:	Conservation through restoration of wild nutmeg tree populations of Western Ghats of Kerala
2.	Department/Organization implementing the project	:	Kerala Forest Research Institute, Peechi
3.	Special Area of study	:	i. Exploration and Identification of wild nutmeg tree populations in the Western Ghats of Kerala. ii. Conservation strategies (Propagule collection, Vegetative and Seed studies, Planting stock production). iii. Restoration and post restoration evaluation. iv. Imparting hands on training on *Nursery practices, plant production and field planting* to the forest staff.
4.	1. Name of the Principal Investigator	:	**Dr. P.A. Jose** Scientist E1, Forest Ecology Department, Forest Ecology and Sustainable Forest Management Division. (Tree Physiology Department and Sustainable Forest Management Division Since August 2015)
	2. Name of Project Associate		**Dr. P.K. Chandrasekhara Pillai** Scientist-C, Forest Seed Centre, Sustainable Forest Management Division.
	3. Name of the Research Personnel	:	**Mr. C. V. Ranjith** Research Fellow (Upto 2nd March 2016)
5.	Name of the Funding Agency	:	Kerala Forest Development Fund, Kerala Forest Department, Thiruvananthapuram
6.	Duration of the Project	:	March 2013- March 2016 (3 years)
7.	Particulars of the Report	:	Final Technical Report

CONTENTS

ACKNOWLEDGEMENTS

The conduct of the project was made possible by the award of Kerala Forest Development Fund of Kerala Forest Department, Thiruvananthapuram. The Investigators expresses their deep sense of gratitude and thanks:

- to Dr. P. G. Latha, Director in Charge; Dr. P.S. Easa, Former Director in Charge, Prof. (Dr.) V.N. Rajasekhara Pillai, Former Director in Charge and Former Executive Vice President, Kerala State Council for Science, Technology and Environment (KSCSTE), for constant encouragement, facilities and personal interest in the implementation of the project.
- to the Wildlife Warden, Shendurney WLS, Divisional Forest Officers, Vazhachal, North Wayanad, Thiruvananthapuram, Thenmala and Range Officers/Deputy Range Forest Officers, Section Forest Officers of the Ranges/WLS such as Kulathupuzha, Central Nursery Kulathupuzha, Neriamangalam, Nagarampara, Sholayar, Aryankavu, Perya Shendurney, Agali, and Meppadi for enthusiastic participation and providing logistic support in the field.
- to Dr. E.A. Jayson Research Coordinator, Dr. M. Balagopalan Former Research Coordinator KFRI for academic support during the project period.
- to Dr. U.N. Nandakumar, Programme Coordinator, SFM Division and Dr. K.K. Ramachandran, Former Programme Coordinator FE & BC Division for their constant support during the period of study.
- to Dr. K. Swarupanandan, Retired Scientist KFRI, Dr. N. Sasidharan, Emeritus Scientist, KFRI and Dr. Shambhu Kumar, Scientist, KFRI for scrutinizing the report and suggestions provided.
- to the Registrar, Deputy Registrars and to all the Staff of KFRI for administrative assistance.
- to the Staff, Forest Seed Centre, Library and Engineering Department, KFRI, for their constant support during the course of study.
- to all my Division colleagues specially Mr. Siju Tom Kuruvila, Mr, K. V. Jithin, M. Sumod, Research Fellows; Mr. N. M. Binoy, Mr. T. V. Sarath and Mr. K. Subin, Project Assistants and other field men working in the Garden Nursery and Medicinal Plant Garden for their support and assistance to complete the project successfully.

Investigators

ABSTRACT

This study on wild nutmegs has been carried out with thrust on identifying major populations of wild nutmegs in the Kerala part of Western Ghats, developing appropriate propagation methods through seed storage practices/ clonal rootability using auxins, raising planting stock, enrichment planting *in situ* and evaluation on seedling survival and growth. The training imparted to the forest staff on the subject signifies and need for similar studies where unscientific and overexploitation of tree resources leads to poor natural regeneration, local endangerment and overall reduction of natural resources.

The major populations of ***Myristica malabarica*** Lam. were identified at Idukki, Thrissur, Kollam and Thiruvananthapuram districts. The seeds with initial moisture content (m.c.) of 30% recorded with 100% germination. The seed viability was found lost within 7 days when the Critical Moisture Content (CMC) reached 17%. The viability of the recalcitrant seeds can be extended upto six months with 30% germinability under storage in closed polythene bags in Seed banking conditions, 20±2°C, 50% RH. The juvenile stem cuttings produced 60% rooting with IBA 1000ppm. The ring air layering was also 100% successful with IAA 1000ppm.

Of the 3900 seedlings raised, 3650 seedlings were planted at Sholayar Range and 200 seedlings at Kulathupuzha Range including casualty planting at Sholayar. The seedling survival recorded 75% at Sholayar after 1.6 years of planting and 80% survival after 6 months at Kulathupuzha.

The major populations of ***Myristica beddomei*** King explored in the districts Wayanad, Palakkad and Thiruvananthapuram. The seeds with initial m.c. of 40% recorded with 63% germination. The viability was found lost after 8 days under normal room conditions when the CMC was dropped down to 12%. The longevity of the recalcitrant seeds could be extended upto seven months with 25% germinability under storage in closed polycarbonate bottles in Seed banking conditions, 20±2°C, 50% RH. The ring air layering in juvenile plants achieved with 75% success with IAA 1000ppm whereas no promising results obtained for stem cuttings. Out of the 1000 seedlings raised in the nursery, 500 seedlings were planted at Wayanad MPCA and 300 at Shendurney WLS. In addition, 50 seedlings were casualty planted in the Wayanad MPCA. Sixty-five percent seedling survival obtained at Wayanad MPCA after 1.6 years of planting and 84% survival after 6 months at Shendurney.

The major populations of ***M. fatua*** **Houtt. var. *magnifica*** **(**Bedd.**)** Sinclair was identified in the *Myristica* swamps in the

Kulathupuzha Range. The seeds with initial m.c. of 32% recorded 100% germination. The viability of seeds was found lost after 10-12 days under room conditions when the CMC was declined to 20%. Longevity of the recalcitrant seeds could be extended upto five months with 30% germinability under storage in closed polythene bags in Seed banking conditions, 20±2°C, 50% RH. The juvenile stem cuttings produced 75% rooting success with IBA 3000ppm; ring air layering also achieved with 75% success with IAA 3000ppm. Among the 1200 seedlings raised, 1100 seedlings were planted in five swamps of the Kulathupuzha Range. In addition, 50 seedlings were casualty planted in the Sasthanada Swamp. The seedling survival was 90-95% at 6^{th} month after planting.

The major populations of **G*ymnacranthera farquhariana*** (Hook. f. & Thoms.) Warb. were identified in the Idukki, Thrissur, Kollam, Kannur and Kozhikode districts. The seeds with initial m.c. of 36% provided 100% germination. The seed viability was found lost within 10 days under normal room conditions as CMC was reached upto 12% with 40% germinability. Longevity of the recalcitrant seeds can be extend upto eight months with 40% germinability under storage in closed polythene bags in Seed banking conditions, 20±2°C, 50% RH. The juvenile stem cuttings resulted 75% rooting success with IBA 5000ppm. The ring air layering achieved 50%

success with IBA 1000ppm. Among the 2950 seedlings raised, 2600 seedlings were planted at Plavuchal - Dharbapana swamps at Kulathupuzha. In addition, 350 seedlings were casualty planted. The rate of seedling survival was ca.70% after 1.6 years of planting.

The major populations of ***Knema attenuata*** (Hook. f. & Thoms.) Warb. were explored at Idukki, Thrissur, Kollam and Thiruvananthapuram districts. The seeds with initial m.c. of 37% recorded 83% germination. Seed viability was found lost after 8-10 days under normal room conditions when the CMC was reached upto 21% with 40% germinability. Longevity of the recalcitrant seeds can be extend upto six months with 35% germinability under storage in closed polycarbonate bottles in Seed banking conditions, 20±2°C, 50% RH. The ring air layering achieved 75% success with IBA 1000ppm whereas no promising rooting success was recorded for juvenile stem cuttings. Out of 2700 seedlings raised, 1800 seedlings were planted at Sholayar Range and 600 seedlings at Second Mile, Kulathupuzha. In addition, 300 seedlings casualty planted in the Sholayar Range. Seventy percent seedling survival was recorded at Sholayar after 1.6 years of planting and 85% after 6 months at Kulathupuzha.

1. Introduction

Western Ghats of Kerala covers about 11, 270 km^2, and it is estimated that about 29% of the area of Kerala state falls under forest cover; of this 28% is composed of Protected Areas such as Sanctuaries and National Parks established for the conservation of rare and endangered plants and animals. The State holds 5,094 flowering plants of which 1,709 are endemics and among which 493 species are categorized as red listed species (Sasidharan, 2012; Jose *et al.*, 2014). In spite of high species diversity, a large number of plants have been turned to 'rare' or 'endangered' because of various anthropogenic factors. It is evident that rarity often stems from various physical and biological constraints such as habitat destruction, over exploitation, environmental imbalance, reproductive anomalies and unadaptive nature of the species to the changing environment. According to Sharma (2003), about 62% of the natural forests of Kerala are degraded. Of them, moist deciduous forests are the most degraded (78%). This is followed by dry deciduous forests (64%), evergreen forests (45%) and sub tropical forests (24%). It is unfortunate to note that the higher plants, especially trees, are found more vulnerable in a complex ecosystem than other life forms as these are selectively over exploited for resource based utilization and have longer periods of juvenility so that chances of destruction prior to maturity is

high. Paucity of conservation measures has also accelerated the degradation process over time. In this context, endemic, threatened and economically important plants of the Western Ghats merit top priority for conservation by both *ex situ* and *in situ* measures including restoration of natural populations to rescue these species from untimely endangerment.

Conservation strategies and Sustainability

The term 'conservation' may be defined as 'the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generation while maintaining its potential to meet the needs and aspirations of future generations (Roy and Datta, 2003). It is recommended that the critical assessment of the causes of threat is made before advocating any conservation measures for threatened plant species. The *in situ* or habitat conservation programme is the most reliable and acceptable way of conservation measures since natural habitats maintain greater genetic diversity with less expensive maintenance than under cultivation. Moreover, natural home lands provide congenial climate for natural selection which ultimately leads to speciation.

Restoration

Conservation through restoration is an advanced strategy aiming to re-establish or rehabilitate the highly depauperate plant species/ populations

from brink of extinction to a level at which it is no longer in danger. The process would help to create new populations through reintroduction of the species and to rebuild the degraded populations in their natural habitats through restocking of the species (Bramwell, 1991; Pandurangan, 2003; Swarupanandan *et al*., 2013; Jose and Pillai, 2014).

Wild nutmegs of the Western Ghats

There are five wild relatives of the cultivated tree, *Myristica fragrans* Houtt. viz., *Myristica malabarica* Lam., *Myristica fatua* Houtt. var. *magnifica* (Bedd.) Sinclair, *Myristica beddomei* King, *Gymnacranthera farquhariana* (Hook.f. & Thoms.) Warb., and *Knema attenuata* (Hook. f. & Thoms.) Warb. The populations of these species are fragmented and become smaller in size, distributed in the evergreen, swamps to montane forests between 200 to 1300m asl. These species are over exploited for seed aril, widely used in commercial and medicinal applications. The populations of these species have also declined due to poor regeneration as the seeds are recalcitrant (short viability of seeds) and inability for clonal reproduction. The habitat specificity of wild nutmeg tree populations in the evergreen, montane and swamp niches is another hurdle for its establishment and survival beyond *in situ* for domestication. The wild nutmegs are one of

the less investigated groups of plants and having a critical role in the ecological functions of evergreen and swamp forests (Nair, *et al.*, 2007).

In this context, the present study of five wild nutmegs has been carried out with thrust on identifying major populations of these species in the Kerala part of Western Ghats, developing appropriate propagation methods through seed storage practices/ clonal rootability with the aid of auxins, raising planting stock, enrichment planting in their original habitats (evergreen and swamp ecosystems) and their evaluation on successful survival and growth. This field oriented study thus has foreseen conservation of species, management of evergreen and swamp forest ecosystems and finally to the resource based utilization of these fast depleting endemic trees of the Western Ghats.

2. Objectives

i. To explore and identify the wild nutmeg tree populations in the evergreen and swamp forests in Kerala part of Western Ghats.

ii. To collect propagules of the selected species *in situ* (seed and clonal) and production of planting stock through conventional propagation/ multiplication strategies.

iii. To enrich dwindling populations of these species through restoration programmes.

iv. To evaluate post -restoration survival and growth of the planted stocks towards conservation and natural resource management.

v. To impart one day hands on training on 'Nursery practices, plant production and field planting' to the field staff of the Kerala Forest Department where the restoration of wild nutmeg tree seedlings are implemented.

3. Materials and Methods

3.1. Materials

i. ***Myristica malabarica*** Lam.

Family : Myristicaceae

Local name: Kattujathi, Ponnampoo

Status : Vulnerable (IUCN, 2000)

Description

Moderate tree up to 15m height, distributed in the evergreen forests up to 1000m altitude. Endemic to Southern Western Ghats from Konkan south ward. Tree is one of the characteristic species in *Myristica* swamps. Fruits are extensively exploited for its aril locally. Tree is economically important for its wild nutmeg and mace which is used for both medicinal and industrial purposes (Sasidharan, 2011).

ii. ***Myristica beddomei*** King

Family : Myristicaceae

Local name : Chithirapoovu, Pathiripoovu

Distribution : Endemic to S. India and Srilanka

Description

Lofty trees up to 25m height, distributed in the evergreen forests up to 1300m altitude. Endemic to South India and Srilanka. Fruits are extensively

exploited for its aril locally. Tree is economically important for its wild nutmeg and mace which is used for both medicinal and industrial purposes (Sasidharan, 2011).

iii. ***Myristica fatua*** Houtt. **var.** ***magnifica*** (Bedd.) Sinclair

Family : Myristicaceae

Local name: Kothapanu

Status : Endangered (IUCN, 2000)

Description

Large tree, distributed in the swamp forests of lower elevations. Endemic to Southern Western Ghats. It is one of the characteristic species in *Myristica* swamps. Tree is economically important for its wild nutmeg and mace which is used for both medicinal and industrial purposes (Sasidharan, 2011).

iv. ***Gymnacranthera farquhariana*** (Hook.f. & Thoms.) Warb.

Family : Myristicaceae

Local name: Undappayin

Distribution: Endemic to Indo-Malaya

Description

Large tree, distributed in the banks of rivers in the evergreen forests. Endemic to Southern Western Ghats and is one of the characteristic species

in *Myristica* swamps. Tree is economically important for its wild nutmeg and mace which is used for both medicinal and industrial purposes (Sasidharan, 2011).

v. ***Knema attenuata*** (Hook. f. & Thoms.) Warb.

Family : Myristicaceae

Local name : Chorapathiri, Chorappayin

Distribution : Endemic to Western Ghats

Description

Moderate tree up to 20m height, distributed in the evergreen/ semi evergreen forests along streams and water courses. Endemic to Southern Western Ghats and is one of the characteristic species in *Myristica* swamps. Tree is economically important for its wild nutmeg and mace which is used for both medicinal and industrial purposes.

3.2. Study area

The study areas were selected after consulting relevant literature from district floras, herbaria and other leading publications. The field experience of the investigators also complemented to locate the sites.

3.2.1. Population sites of *Myristica malabarica*

The fragmented populations of the species are distributed in most of the districts of the State. The major populations of the *Myristica malabarica* were located and represented (Fig.1).

3.2.2. Population sites of *Myristica beddomei*

The major populations of the *Myristica beddomei* were located and presented (Fig. 2).

3.2.3. Population sites of *Myristica fatua* var. *magnifica*

The populations of the *Myristica fatua* var. *magnifica* were located at *Myristica* swamps in the Kulathupuzha Range, Thiruvananthapuram Division; Thenmala Range in Thenmala Division and at Shendurney WLS. In addition, a few individuals of the species were also located in Sacred grove (Table- 8).

3.2.4. Population sites of *Gymnacranthera farquhariana*

The major populations of *Gymnacranthera farquhariana* were located and depicted (Fig.3).

3.2.5. Population sites of *Knema attenuata*

The populations of the *Knema attenuata* were located and presented (Fig. 4).

3.3. Methods

The wild nutmeg trees viz., *Myristica malabarica*, *Myristica beddomei*, *Myristica fatua* var. *magnifica*, *Gymnacranthera farquhariana* and *Knema attenuata* of the Western Ghats were targeted for large scale multiplication and enrichment planting *in situ* after developing appropriate protocols for conventional propagation. These species were extensively explored in the Western Ghats of Kerala region and their major population areas were mapped out.

Ripe fruits were collected from the populations growing in the respective ecosystems of each species. The fruits were processed by removing the fleshy aril, covering the seeds. The processed seeds were tested for initial moisture content (m.c.) analysis on fresh weight basis and sown for germination in the Nursery (Jose and Pandurangan, 2013). The seeds were subjected for desiccation and freezing temperature conditions in order to identify the seed type. The fresh seed lot with initial m.c. was divided into equal numbers and kept in different storage conditions in the Seed bank for periodic viability and germination test. Seeds were also subjected to suitable pre treatments in order to overcome dormancy, wherever it was found.

The infrastructural facility such as Low poly tunnels with mist irrigation was constructed for large scale propagation, multiplication and establishment of seedlings in the nursery. Conventional rooting of stem cuttings taken from the adult trees and from juvenile plants of 2-3 years old was attempted for rooting with the application of hormones. Stem cuttings were treated with auxins such as IAA, IBA and NAA at different concentrations viz. 1000, 3000 and 5000ppm. Similarly, air layering was also tried in juvenile plants with different concentrations of IAA, IBA and NAA (Jose *et al.*, 1995; Sharma *et al.*, 1995). The seedlings produced as the outcome of seed studies and seedlings germinated out of fallen fruits and ripened fruits collected from different populations of the species were used as the stock for planting (Jose *et al*., 2011).

Appropriate natural ecosystems along with sparse distribution of targeted species were identified in the Kerala part of the Western Ghats for enrichment planting. The entire planting area was divided into approximately equal sub plots for seedling planting and monitoring. Average height of nursery grown plants was recorded before planting and height of 25% of the total seedlings were recorded and tagged serially. The fully established poly bag grown seedlings of two year old with 30-45cm height were transferred from the Nursery to the planting site. Pits of 45x 45 x 45cm

size were taken according to the space avaibility of the area marked. Planting of seedlings were carried out with equal number of tagged along with untagged seedlings in each sub plots. Planting was done during monsoon period (Jose and Pillai, 2014).

The survival of planted seedlings in each site was monitored at 6 months intervals after planting. The height increment of each seedling along with factors affecting for the survival of seedlings were recorded. The planting sites in the natural forest areas have been permanently demarcated by fixing metal display boards with relevant information such as title of the project, funding agency, GPS details of the location, date and number of seedlings planted etc. (Jose and Sumod, 2015).

One day Hands on training on ‘Nursery practices, plant production and field planting’ were imparted to the forest staff in the three Forest Divisions where restoration of the wild nutmegs was carried out. The training included a power point presentation on the topic and demonstrations on nursery practices. A course material in Malayalam was also prepared and distributed to the participants.

4. Results

4.1. *Myristica malabarica* Lam.

The populations located and identified for the species are as follows:

Fig. 1. Population sites of *Myristica malabarica* identified in the Western Ghats of Kerala

i. Kulamankuzhikudi, N 10° 02′ 43.8″ L, E 6° 50′ 11.08″ L. (Neriamangalam Range, Munnar Division), 10 km away from Neriamangalam town, enroute Adimali, Alt. 504m; The populations are located in a semi- evergreen, secondary type forest patch.

ii. Kulamavu MPCA (Medicinal Plant Conservation Area), N 9° 49′ 14.8″ L, E 76° 54′ 17.6″ (Nagarampara Range, High Range Division, Kottayam) Alt. 867m; the populations are located in the evergreen forests.

iii. Sholayar- Malakkapara, N 10° 18′ 00.8″, E 76° 46′ 47.3″ (Sholayar Range, Vazhachal Division). Alt. 850m. The populations are located in the evergreen forests.

iv. Rosemala forest areas lie in N° 08 16′ 9.29″ L, E 77° 00′ 1.75″ (Shendurney WLS). Alt. 490m. The populations are located in the evergreen forest.

Propagule collection

Ripe fruits of the species were collected from the populations growing in the semi evergreen forests at Valera of Neriamangalam Range. Fruits of the species were also harvested from the evergreen forests at Kulamavu MPCA within the Nagarampara Range.

Seed propagation (Seed storage, Viability and Germination)

The ripe fruits (Capsule) are cylindrically oblong and brown tomentose in texture. The seeds are hard in nature and have shown to be polymorphic. The ripe fruits and seeds were measured for average length, diameter and weight attributes (Table- 1).

Table -1. Fruit and Seed attributes of *M. malabarica*

Sl No.	Fruit/Seed	Average length	Average diameter	Average weight
1.	Fruit	63.4mm	39.0mm	57.0g
2.	Seed	39.5mm	18.5mm	10.0g

The fresh seeds with initial moisture content of 30% registered 100% germination after 28-32 days using river sand as the sowing medium in nursery conditions. The seeds lost viability within 7 days when stored in open plastic trays in ambient conditions (control). Critical Moisture Content (CMC) noted was 17% for 25% germination. The fresh seeds with initial m.c. of 30% under storage have shown varied viability periods: 4 months with 25% germination in closed poly carbonate bottle (Ambient), 4 months with 17% germination in closed polythene bags (Ambient), 3 months with 30% germination in polybags contained wet saw dust (Ambient), 1 month with 30% germination in open plastic tray (Seed bank 20±2°C, 50% RH), 4 months with 30% germination in closed poly carbonate bottle (Seed bank 20±2°C, 50% RH), 2 months with 17% germination in open plastic tray (Seed bank 16±2°C; 45% RH), 5 months with 33% germination in closed poly carbonate bottle (Seed bank 16±2°C; 45% RH), 5 months with 20% germination in polybags (Seed bank 16±2°C; 45% RH). Maximum viability upto 6 months with 30% germination obtained when stored in closed polybags in controlled Seed banking conditions at 20°C ± 50% RH (Table- 2). The germination type is hypogeal.

Vegetative propagation

Aged branch cuttings were found difficult for rooting; however juvenile stem cuttings taken from have shown callus and root formation. Around 60% of the cuttings treated with IBA at 1000ppm rooted within 80-120 days. In the case of air layering, young stands rooted within 90-130 days. Layering with IAA at 1000ppm gave 100% success whereas 50% success was noted in the control (Table-3&4). The reiterating ability has ensured the continuous growth of the plant even after separation of layers from the main stock.

Planting stock production

A total of 3,900 seedlings of the species were raised in polybags and maintained in the nursery as part of the restoration of the species *in situ* (Plate -1).

Enrichment planting (Restoration) and post restoration evaluation

Two natural evergreen ecosystems in the Western Ghats of Kerala region such as Malakkapara and Kulathupuzha were selected for *in-situ* planting. A total of 3700 seedlings with height ranged from 29-33cm were planted in two natural habitats (Table - 20). In addition, 150 seedlings were casualty planted at Malakkapara. The seedlings showed slow growth in all the sites. Wilting of seedlings was noticed in the planted areas due to the poor South West monsoon in the planting year.

1. Malakkapara

Around 3500 seedlings of 1.0-1.6 years old were planted at Chandanthodu near Malakkapara. The mean height of seedlings during planting was 29cm and the maximum height was 41 cm. The seedlings showed 75% survival along with an average height of 45cm and maximum height of 65cm after 1.6 years of planting. The survival of plants was found affected by varied interventions particularly by the Guar and Elephant trampling. Pest incidence by of insects of the sub class Collembola was found damaging the growing shoot of the seedlings occasionally.

2. Kulathupuzha

Around 200 seedlings of 1.0 - 1.6 yrs. old were planted in the evergreen patch at Second Mile. The mean height of seedlings during planting was 32cm and the maximum height was 45cm. Planting of the seedlings were done during the month June 2015. The seedlings showed 80% survival along with average height of 36cm and a maximum height of 50cm after six months of planting (Plate -2).

Table -2. Effect of storage conditions on the Moisture content and Germination of *Myristica malabarica* seeds

Sl. No.	Seed type	Container	Condition/ Temp.	Moisture content/ Germination	Moisture content/ Germination (%) after storage(months)						
					1	2	3	4	5	6	7
1	Fresh (30% m.c.)	Open plastic tray	Ambient (25°C, RH-60%)	MC	-	-	-	-	-	-	-
				G	-	-	-	-			
2	Fresh (30% m.c.)	Closed polycarbonate bottle	Ambient (25°C, RH-60%)	MC	34	32	33	30	30	-	-
				G	70	67	40	25	0		
3	Fresh (30% m.c.)	Closed polythene bag	Ambient (25°C, RH-60%)	MC	30	27	33	31	32	29	-
				G	83	60	30	17	0	0	
4	Fresh (30% m.c.)	Closed polybag in sawdust	Ambient (25°C, RH-60%)	MC	23	20	19	17	-	-	-
				G	50	40	30	-			
5	Fresh (30% m.c.)	Open plastic tray	Seed Bank (20±2°C, 50%RH)	MC	26	16					
				G	30	0					
6	Fresh (30% m.c.)	Closed polycarbonate bottle	Seed Bank (20±2°C, 50%RH)	MC	32	33	35	32	30	-	-
				G	90	70	50	20	0		
7	Fresh (30% m.c.)	Closed polythene bag	Seed Bank (20±2°C, 50%RH)	MC	29	31	33	34	32	26	24
				G	80	70	67	60	80	30	0
8	Fresh (30% m.c.)	Closed polybag in sawdust	Seed Bank (20±2°C, 50%RH)	MC	27	24	22	17	-		
				G	70	50	20	0	-		
9	Fresh (30% m.c.)	Open plastic tray	Seed Bank (16±2°C, 45%RH)	MC	25	18	12	-	-	-	-
				G	30	17	0	-	-	-	-
10	Fresh (30% m.c.)	Closed polycarbonate bottle	Seed Bank (16±2°C, 45%RH)	MC	32	35	33	30	31	28	-
				G	80	80	70	40	33	0	-
11	Fresh (30% m.c.)	Closed polythene bag	Seed Bank (16±2°C, 45%RH)	MC	29	31	32	29	27	-	-
				G	70	67	50	50	20	-	-

Note : Fresh seeds on sowing resulted 100% germination with initial 30% m.c.
Legend : MC- Moisture content (%), G- germination (%)

Table- 3. Vegetative propagation through stem cuttings in *Myristica malabarica*

Treatment (ppm)	Rooting (%)	Mean no. of roots (Mean ± SD) (cm)	Mean length of roots (Mean ± SD) (cm)	Survival of ramets (%)
Control	13	1.33 ± 0.96	1.60 ±1.27	100
IAA 1000	13	1.70 ± 1.43	1.20 ± 1.41	100
IAA 3000	0	-	-	-
IAA 5000	0	-	-	-
IBA 1000	60	2.00 ± 1.32	1.60 ±1.27	100
IBA 3000	33	2.50 ± 0.96	4.90 ± 0.41	100
IBA 5000	20	4.00 ± 1.51	6.31 ± 1.50	100
NAA 1000	13	1.70 ± 0.87	2.00 ± 1.39	100
NAA 3000	-	-	-	-
NAA 5000	25	2.66 ± 0.68	3.00 ± 0.53	100

Table -4. Vegetative propagation through air layering in *Myrstica malabarica*

Sl. No.	No. of layers done	Treatment/ Control	Rooting (%)	Survival (%)
1	4	Control	50	100
2	4	IAA 1000	100	100
3	4	IBA 1000	50	50
4	4	NAA 1000	75	100

Plate-1. *Myristica malabrica*

a. Fruiting branch **Figs. b-c.** Ripened friuts and seeds with aril

Figs. d-e. Seed germination in the lab and field

Clonal rooting success : **f.** Air layering success **g.** stem rooting **h.** Planting stock

Plate 2. *Myristica malabarica*

Figs. a-b. Stages of *in situ* planting

Figs. c-e. Planted seedling, monitoring and metal board display at Malakkapara site

Figs. f-h. Seedling planting and metal board display at Kulathupuzha site

4.2. *Myristica beddomei* King

The populations located and identified for the species are as follows:

i. Varadimala, N 11° 01′ 39.6″ L, E 76° 41′ 47.4" L. (Agali Range, Mannarkad Division). Alt. 1320m; the populations are located in a semi-evergreen secondary type forest patch.

ii. Karadippara, N 11° 01′ 43.8″ L, E 76° 46′ 47.3″ (Agali Range, Mannarkad Division). Alt. 850m; the populations are located in the evergreen forests.

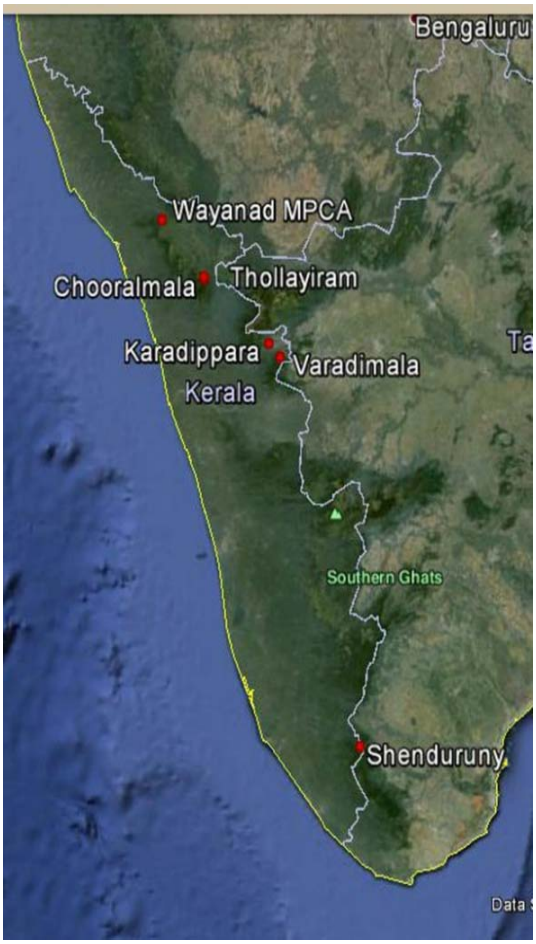


Fig. 2. Population sites of *Myristica beddomei* identified in the Western Ghats of Kerala

iii. Wayanad MPCA N 11° 51′ 3.19″, E 75° 48.6′ 5.94″ (Chandanathodu, Perya Range, North Wayanad Division). Alt. 800m. The populations are located within the evergreen forests.

iv. Chooralmala and Thollayiram forest areas lie at N 11° 01′43.8″ L, E 76° 35′ 32.2″, Meppadi Range, South Wayanad Division). Alt. 850m. The populations are identified in semi-evergreen secondary type forest patch.

v. Shenduruney WLS (Wildlife Sanctuary), N 08˚50 ' 88.7″, E 077˚10' 58.5″. Alt. 860 m. The populations are identified with in the evergreen forest.

Propagule collection

Ripe fruits of the species were collected from the populations growing in the evergreen/semi-evergreen forests at Varadimala and at Karadipara within the Agali Range. The populations are located with a geographical distribution of 11˚ 01' 39.6" N latitude and 76˚ 41' 47.4 E" longitude at an altitude between 1320-1330m asl. and 11˚ 01' 43.8" N latitude and 76˚ 3'5 32.2 E " longitude at an altitude between 850-900m asl respectively. The ripe fruits were also collected from the evergreen forests at Chooralmala and Thollayiram forest areas within the Meppadi Range with a geographical distribution of 11˚ 01' 43.8" N latitude, 76˚ 3'5 32.2 E " longitude between 850-900m asl.

Seed propagation (Seed storage, Viability and Germination)

The ripe fruits and seeds were measured for average length, diameter and weight attributes (Table- 5).

Table 5. Fruit and Seed attributes of *M. beddomei*

Sl No.	Fruit/Seed	Average length	Average diameter	Average Weight
1.	Fruit	63.4mm	60.0mm	77.0g
2.	Seed	39.5mm	35.5mm	19.0g

The fresh seeds with initial moisture content of 40% resulted 63% germination in 55-90 days using river sand as the sowing medium in nursery conditions. The seeds kept in open plastic trays at ambient conditions (control) lost viability within 8 days. Critical MC at 12% resulted 40% germination. The viability of the seeds can be extend up to 7 months with 25% germination by storing in closed polycarbonate bottle in controlled seed banking conditions at 20°C ± 50% RH (Table 6). The germination type was hypogeal. The dormancy breaking experiments showed 100% germination with the treatment of GA_3 @ 500ppm of 5 minutes dipping compared to 63% germination in the control. The germination was also found preponed five days than the control trials.

Vegetative propagation

No promising results were recorded for stem cuttings. However, in the case of air layering, young stands of 2 years old have responded positively and rooted within 90-130 days. Layering with IAA at 1000ppm gave 75%

success whereas only 50% success noted in the control (Table-7). The reiterating ability has ensured the continuous growth of the plant even after separation of air layers from the main stock.

Planting stock production

The ripened and fallen fruits/ seeds were often predated by wild boar and porcupines and caused poor regeneration of the species *in situ*. The seeds of the species have shown poor germination rate *ex situ* as dormancy played a crucial role. A total of 1000 seedlings of the species were raised in polybags and maintained in the nursery as part of the restoration of the species *in situ* (Plate -3).

Enrichment planting (Restoration) and post restoration evaluation

Two natural evergreen ecosystems in the Western Ghats of Kerala region such as Wayanad MPCA and Shendurney WLS were selected for *in situ* planting.

A total of 800 seedlings with an average height of 26-32cm were planted in the identified natural habitats (Table-20). In addition, 50 seedlings were casualty planted at Wayanad MPCA. The seedlings showed slow growth in all the sites. Wilting of the seedlings was noticed in the planted areas due to the poor South West monsoon in the planting year.

1. Wayanad MPCA

Around 500 seedlings were planted at Chandanathodu in Wayanad MPCA. The mean height of seedlings during planting was 26cm and the maximum height was 41cm. The seedlings showed 65% survival along with average height of 36cm and maximum height of 51cm after 1.6 years of planting. The survival of plants was found affected by varied interventions, wildlife by the Guar and Elephant.

2. Shendurney WLS

Around 300 seedlings were planted in the site. The mean height of seedlings during planting was 31cm and the maximum height was 56 cm. The planting of the seedlings were done during the month of June 2015. The seedlings showed 84% survival along with average height of 33cm and a maximum height of 59cm after six month of planting (Plate- 4).

Table 6. Effect of storage conditions on the Moisture content and Germination of *M. beddomei* seeds

Sl. No.	Seed type	Container	Condition/ Temp.	Moisture content / Germination	Moisture content/ Germination (%) after storage (months)							
					1	2	3	4	5	6	7	8
1	Fresh (40% m.c.)	Open Plastic tray	Ambient (25°C, RH-60%)	MC G	- 	- 	- 	- 	- 	- 		-
2	Fresh (40% m.c.)	Closed polycarbonate bottle	Ambient (25°C, RH-60%)	MC G	42 60	39 45	35 30	42 -				
3	Fresh (40% m.c.)	Closed polythene Bags	Ambient (25°C, RH-60%)	MC G	39 67	33 40	22 0	- -	- -			
4	Fresh (40% m.c.)	Open Plastic tray	Seed Bank (20±2°C, 50% RH)	MC G	24 0	18 0	- -					
6	Fresh (40% m.c.)	Closed polycarbonate Bottle	Seed Bank (20±2°C, 50% RH)	MC G	41 70	39 63	37 50	39 45	39 50	42 30	41 25	40 0
7	Fresh (40% m.c.)	Closed polythene Bags	Seed Bank (20±2°C, 50% RH)	MC G	39 50	37 63	35 50	39 40	43 20	41 0		
9	Fresh (40% m.c.)	Open Plastic tray	Seed Bank (16±2°C, 45% RH)	MC G	18 0	- -						
10	Fresh (40% m.c.)	Closed polycarbonate Bottle	Seed Bank (16±2°C, 45% RH)	MC G	40 60	36 55	38 40	38 0				
11	Fresh (40% m.c.)	Closed polythene bags	Seed Bank (16±2°C, 45% RH)	MC G	42 63	38 67	35 17	28 0	-			

Note: Fresh seeds on sowing resulted 63% germination with initial 40% m.c.
Legend: MC- Moisture Content (%), G - germination (%)

Plate- 3. *Myristica beddomei*

a. Habit

b. Fruiting branch

Figs. c-d. Ripened friuts and seeds with aril

e. Seed germination

f. Air layering success

g. Planting stock

Plate - 4. *Myristica beddomei*

Figs. a-b. Planting stock and seedling planting at Wayanad MPCA

Figs. c-e. Seedling planting, monitoring and display of metal board at Wayanad MPCA

Figs. f-h. seedling planting, monitoring and display of metal board at Shenduruney WLS

Table 7. Vegetative propagation through air layering in *M. beddomei*

Sl. No.	No. of layers done	Treatment/ Control	Percent of rooting	Survival %
1	4	Control	50	100
2	4	IAA 1000	75	100
3	4	IBA 1000	25	100
4	4	NAA 1000	-	-

4.3. *Myristica fatua* Houtt. var. *magnifica* (Bedd.) Sinclair

The populations of the *Myristica fatua* var. *magnifica* were located at 19 *Myristica* swamps in the Kulathupuzha Range, Thiruvananthapuram Division; Thenmala Range in Thenmala Division and at Shendurney WLS. In addition, a few individuals of the species were also located at Vallikattukavu Sacred grove at Chelannur (Kozhikode Dist.) (Table -8).

Table 1. Populations of *M. fatua* var. *magnifica* located in different *Myristica* swamps

Sl. No.	Name of Swamp	Forest Range	Site features	Altitude
1.	Ammyambalam	Kulathupuzha	08°50' 20.2" N ; 077° 02' 11.6"E	154m
2.	Karikurinji	Kulathupuzha	08° 49'10.5" N, 77°04' 59" E	138m.
3.	Sasthnada	Kulathupuzha	08°49'10.5" N, 77°03'04.0" E	156m.
4.	Mottalmoodu	Kulathupuzha	08°53'00.4"N, 77°05' 00.5"E	138m
5.	Marappalam Major	Kulathupuzha	08°52'46.0"N, 77°05'21.5"E	190m
6.	Marappalam Minor	Kulathupuzha	08°52'51.4"N, 77°05‘10.7"E	190m
7.	Pallithadam	Kulathupuzha	08°48'46.33"N, 77°02'58.5"E	189m
8.	UthiranChira	Kulathupuzha	08°48'10.1"N, 077°02'24.2"E	197m
9.	Pelicode	Kulathupuzha	08°48'12.6"N, 077°02'27.1"E	181m
10.	Muppathadi	Kulathupuzha	08°49'07.3"N, 077°03'17.7"E	157m
11.	Chekidichal	Kulathupuzha	08°48'31.7"N, 077°03'20.6"E	165m
12.	Empong	Kulathupuzha	08°53'31.06"N, 077°03'40.6"E	160m
13.	Plavuchal	Kulathupuzha	08°52'19.3"N, 077°05'03.0"E	162m
14.	Dalley karikkom	Kulathupuzha	08°51'30.6" N,077°03'27.9"E	170m
15.	Channamala	Kulathupuzha	08° 52' 54.2" N, 077° 04' 29.9" E	179m
16.	Vallikattukavu	Sacred grove at Chelannur (Kozhikode)	11°23'16.0"N, 075°47'19.1"E	47m
17.	Peruvazhikala	Thenmala	08°53'49.5"N, 077°04'47.7"E	166m
18.	Kundan chathachathuppu	Thenmala	08°53'39.6"N, 077°04'13.1"E	165m
19.	Katlapara	Shendurney WLS	08° 54' 40" N, 077° 6' 47" E	160m

Propagule collection

The ripe fruits of the species were collected from the Mottalmoodu, Channamala and Marappalam swamp forest areas at Kulathupuzha Range.

Seed propagation (Seed storage, Viability and Germination)

The ripe fruit is a capsule, oblong-ovoid, covered with tomentum. The ripe fruits and seeds were measured for average length, diameter and weight attributes (Table-9).

Table-9. Fruit and seed attributes of *M. fatua* var. *magnifica*

Sl No.	Fruit/Seed	Average length	Average diameter	Average weight
1.	Fruit	85.4mm	64.0mm	88.0g
2.	Seed	39.5mm	35.58mm	22.0g

The processed seeds were then subjected for initial moisture content analysis on fresh weight basis and sown for germination in the Nursery. The fresh seeds with an initial moisture content of 32% exhibited 100% germination within 35-45 days in the nursery conditions. The seeds lost viability within 10-12 days at C.M.C. of 20% with 30% germinability under ambient conditions. The viability of the seeds could be extended upto 5 months with 30% germinability under controlled Seed banking conditions

(Table -10). The seeds were found sensitive towards desiccation and freezing conditions and therefore categorized under recalcitrant category.

Vegetative propagation

Aged branch cuttings were found difficult for rooting; however juvenile stem cuttings taken from 2-3 yrs. old saplings have shown callus formation. Around 75% of the cuttings treated with IBA at 3000ppm rooted within 80-120 days. The air layering in young stands of 2 year old with the treatment of IAA 3000ppm gave 75% rooting within 40-75 days of girdling (Table -11& 12). The reiterating ability has ensured the continuous growth of the plant even after separation of air layers from the main stock.

Table -10. Effect of storage condition on the Moisture content and Germination of *M. fatua* var. *magnifica* seeds

Seed type	**Container**	**Condition / Temp.**	**Moisture content / Germination**	**Moisture Content/ Germination (%) after storage (months)**					
				1	2	3	4	5	6
Fresh (32% m.c.)	Open plastic tray	Ambient (25°C/ 60% RH)	MC	18	-				
			G	0	-				
Fresh (32% m.c.)	Open plastic tray	Seed Bank (20±2°C, 50% RH)	MC	21	-				
			G	20	-				
Fresh (32% m.c.)	Closed polythene bag	Seed Bank (20±2°C, 50% RH)	MC	32	30	25	22	24	20
			G	100	60	60	50	30	0
Fresh (32% m.c.)	Closed polycarbonate bottle	Seed Bank (20±2°C, 50% RH)	MC	32	32	30	-		
			G	80	50	40			

Note: Fresh seeds on sowing resulted 100% germination with initial 32% m.c.

Legend: MC- Moisture content (%), G- Germination (%).

Table- 11. Vegetative propagation through stem cuttings in *Myrstica fatua* var. *magnifica*

Treatment (ppm)	Rooting (%)	Mean no. of roots (Mean ± SD) (cm)	Mean length of roots (Mean ± SD) (cm)	Survival of ramets (%)
Control	13	1.50 ± 0.87	4.00 ± 1.39	100
IAA 1000	20	1.66 ± 0.68	3.00 ± 0.53	100
IAA 3000	-	-	-	-
IAA 5000	-	-	-	-
IBA 1000	20	-	-	-
IBA 3000	75	2.50 ± 0.96	7.90 ± 0.41	100
IBA 5000	50	3.00 ± 1.51	8.31 ± 1.50	100
NAA 1000	13	1.70 ± 0.87	2.00 ± 1.39	100
NAA 3000	25	2.66 ± 0.68	3.00 ± 0.53	100
NAA 5000	-	-	-	-

Table - 12. Propagation through air layering in *M. fatua* var. *magnifica*

Sl. No.	No. of layers done	Treatment/ Control	Rooting (%)	Survival (%)
1	4	Control	25	100
2	4	IAA 1000	70	100
3	4	IBA 1000	25	100
4	4	NAA 1000	50	100
5	4	IAA 3000	75	100
6	4	IBA 3000	25	100

Planting stock production

A total of 1200 seedlings of the species were raised in polybags and maintained in the nursery for planting activity as part of the restoration of the species *in situ* (Plate-5).

Enrichment planting (Restoration)

Myristica swamp forest ecosystems located at Kulathupuzha Forest Range have been identified for *in-situ* recovery planting (Table 20). A total of 1000 seedlings with an average height of 70cm were planted in four *Myristica* swamps in Kulathupuzha Range. Another 100 seedlings were handed over to Research Wing, Kulathupuzha at Chozhiyakode for planting. Further, 50 seedlings were casualty planted in two swamps.

1. **Ammayambalam**

Around 250 seedlings of 1.0-1.6 years old were planted at Ammyambalam *Myristica* Swamp in Kulathupuzha. The mean height of seedlings during planting was 70cm and the maximum height was 110cm. The seedlings showed 90% survival along with average height of 72cm and maximum height of 110cm after 6 months of planting. The survival of plants was found affected by Elephant trampling.

2. **Perumpadappy**

Around 300 seedlings of 1.0 - 1.6 years old were planted at Perumpadappy *Myristica* Swamp in Kulathupuzha. The mean height of seedlings during planting was 70cm and the maximum height was 100cm. The seedlings showed 90% survival along with average height of 73cm and maximum height of 100cm after 6 months of planting. The survival of plants was found affected by varied interventions particularly by the Elephant trampling.

3. Sasthanada

Around 100 seedlings of 1.0-1.6 years old were planted at Sasthanada *Myristica* Swamp in Kulathupuzha. The mean height of seedlings during planting was 70cm and the maximum height was 100cm. The seedlings showed 90% survival along with average height of 73cm and maximum height of 102cm after 6 months of planting. The survival of plants was found affected adversely by Elephant trampling.

4. Pullumala

Around 300 seedlings of 1.0 - 1.6 years old were planted at Pullumala *Myristica* Swamp in Kulathupuzha. The mean height of seedlings during planting was 70cm and the maximum height was 100cm. The seedlings showed 95% survival with average height of 74cm and maximum height of

Plate 5 - *Myristica fatua* var. *magnifica*

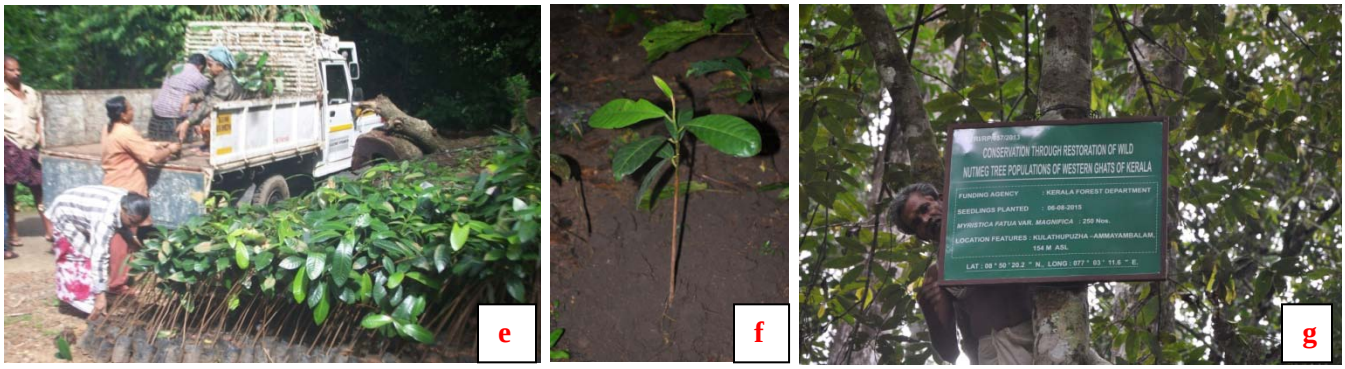
a. Habit **b. Habitat**

c. Seeds with aril **Figs. d-e stem rooting and air layering success**

Figs. f-h. Seed germination and established seedlings in the nursery

Plate 6. *Myristica fatua* var. *magnifica*

Figs. a-d. Seedling planting, monitoring and metal board display at Sasthanada swamp



Figs. e-g. Views of seedling shifting, planted seedling and metal board displayed at Ammayambalam swamp

Figs. h-k. Seedling planting, monitoring and display board fixed at Perumpadappy & Pullumala *Myristica* Swamps

105cm after 6 months of planting. The survival of plants was found affected by varied interventions particularly by the Elephant trampling (Plate -6).

4.4. *Gymnacranthera farquhariana* (Hook.f. &Thoms.) Warb.

The populations located and identified for the species are as follows:

i. *Myristica* swamps in Kulathupuzha Range, Thiruvananthapuram Division, and Thenmala Range in Thenmala Division.

ii. Kulamankuzhikudi, N 10° 02′ 35.2″ L, E 76° 50′ 11.08″ L. (Neriamangalam Range, Munnar Division), 10 km away from Neriamangalam town, enroute Adimali, Alt. 504m; The populations are located in a semi-evergreen secondary type forest patch.

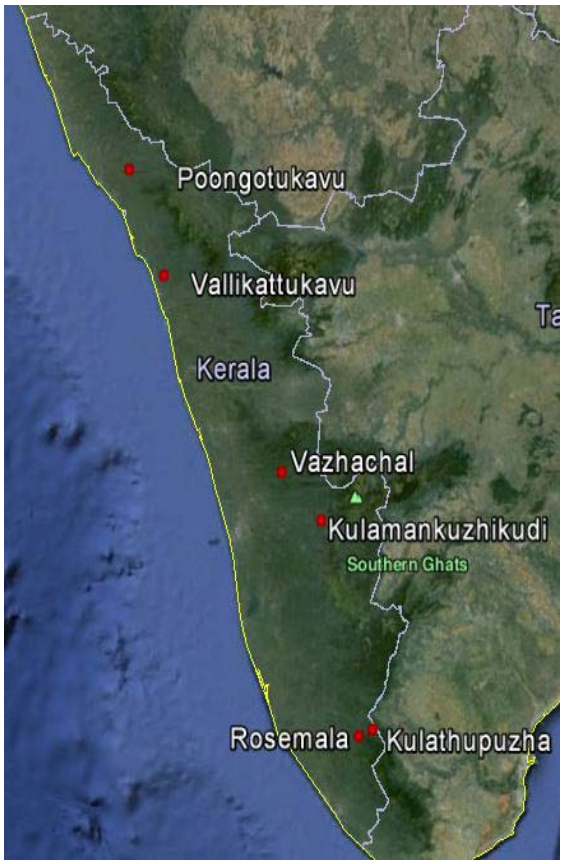


Fig. 3. Population sites of *G. farquhariana* identified in the Western Ghats of Kerala

iii. Rosemala forest areas lies in N 08° 16′ 9.29″ L, E 77° 00′ 1.75″ (Shendurney WLS). Alt. 490m. The populations are identified in the evergreen forest.

iv. Vallikattukavu Sacred grove at Chelannur (Kozhikode Dist.). N 11°23'16.0"L, E 075°47'19.1"L. Alt. 47m.

v. Poogottukavu Sacred grove at Mattannur (Kannur Dist.) N 11°55' 08.9 " L, E 75° 36' 57.4" L. Alt. 95m.

vi. Vazhachal, N 10° 18′ 00.8″, E 76° 46′ 47.3″ (Vazhachal Range, Vazhachal Division). Alt. 400m. The populations are located within the evergreen forests.

Propagule collection

Ripe fruits of the species were collected from the evergreen forests at Valera of Neriamangalam Range and from the populations growing in the Mottalmoodu *Myristica* swamp at Kulathupuzha Range with a geographical distribution of 8° 52' 59.9" N latitude and 77° 04' 59.0" E longitude at an altitude 120m asl.

Seed propagation (Seed storage, Viability and Germination)

The ripe fruit a capsule, glabrous and with thick rind. The ripe fruits and seeds were measured for average length, diameter and weight attributes (Table -13).

Table -13. Fruit and seed parameters of *Gymnacranthera farquhariana*

Sl No.	Fruit/Seed	Average length	Average diameter	Average weight
1.	Fruit	30.7mm	29mm	12.9g
2.	Seed	20.1mm	20.1mm	3.2g

The fresh seeds with initial moisture content of 36% resulted 100% germination in 45-55 days using river sand as the sowing medium in nursery conditions. The seeds lost viability within 10 days during storage in open plastic trays in ambient conditions (control). Critical MC was noted at 12% with 40% germination. The seeds under storage have shown varied viability period viz. 4 months with 100% germination in closed poly carbonate bottle (Ambient), 3 months with 67% germination in closed polythene bags (Ambient), 7 months with 30% germination in closed polycarbonate bottle (Seed bank 20±2°C, 50% RH), 4 months with 50% germination in polybags (Seed bank 16±2°C, 45% RH), 3 months with 67% germination in poly bags contained wet saw dust (Seed bank 20±2°C, 50% RH). Maximum viability upto 8 months was recorded with 40% germination during storage in closed polybags in controlled Seed banking conditions at 20°C ± 50% RH (Table 14). The germination type is hypogeal.

Vegetative propagation

Aged branch cuttings were found difficult for rooting; however juvenile stem cuttings taken from have shown root formation. Around 75% of the cuttings treated with IBA at 5000ppm rooted within 120 days. In the case of air layering, IBA at 1000ppm have resulted 50% success. IAA and NAA had no effect on rooting. Continuous growth of the plant after separation of air layers from the main stock was obvious (Table -15 & 16).

Planting stock production

A total of 2950 seedlings of the species were raised in polybags and maintained in the nursery for planting activity as part of the restoration of the species *in situ* (Plate -7).

Enrichment planting (Restoration) and Post restoration Evaluation

The natural swamp ecosystems in the Western Ghats of Kerala region were selected for *in-situ* recovery planting. A total of 2500 seedlings were planted in one natural habitat of the species (Table -20). Fully established 1.5 – 2 years old poly bagged seedlings having an average height of 40cm were transported from the nursery to the planting sites. Another 100 seedlings were handed over to Research Wing, Kulathupuzha at

Chozhiyakode for planting. Further, 350 seedlings were casualty planted in the sites. The seedlings showed slow growth in all the sites. Wilting of seedlings was noticed in the planted areas due to the poor South West monsoon in the planting year.

1. Kulathupuzha

Around 2500 seedlings of 1.0 - 1.5 yrs. old were planted in Plavuchal and Darbapana *Myristica* swamp at Second Mile, Kulathupuzha. The mean height of seedlings during planting was 40cm and the maximum height was 65 cm. The seedlings showed 70% survival along with average height of 47cm and maximum height of 70cm after 1.6 years of planting (Plate-8).

Table -14. Effect of storage condition on the Moisture content and Germination of *Gymnacranthera farquhariana* seeds

Sl. No.	Seed type	Container	Condition/ Temp.	Moisture content / Germination	Moisture content/ Germination (%) after storage (months)								
					1	2	3	4	5	6	7	8	9
1	Fresh (36% m.c.)	Open plastic tray	Ambient (25°C, RH-60%)	MC G	-	-	-	-	-	-			-
2	Fresh (36% m.c.)	Closed polycarbonate bottle	Ambient (25°C, RH-60%)	MC G	37 90	38 0	35 0	34 100					
3	Fresh (36% m.c.)	Closed polythene bag	Ambient (25°C, RH-60%)	MC G	35 100	35 83	34 67	32 0	- -				
4	Fresh (30% m.c.)	Closed polybag in sawdust	Ambient (25°C, RH-60%)	MC G	36 90	38 100	22 0	- -					
5	Fresh (30% m.c.)	Open plastic tray	Seed Bank (20±2°C, 50%RH)	MC G	32 80	29 83	17 20		14				
6	Fresh (30% m.c.)	Closed polycarbonate bottle	Seed Bank (20±2°C, 50%RH)	MC G	35 60	37 33	34 83	35 70	36 70	34 63	32 50	28 0	25 0
7	Fresh (30% m.c.)	Closed polythene bag	Seed Bank (20±2°C, 50%RH)	MC G	36 100	40 83	43 100	37 67	36 83	38 67	35 50	32 40	
8	Fresh (30% m.c.)	Closed polybag in sawdust	Seed Bank (20±2°C, 50%RH)	MC G	36 100	35 100	33 80	30 70	25 67				
9	Fresh (30% m.c.)	Open plastic tray	Seed Bank (16±2°C, 45%RH)	MC G		8 0	- -						
10	Fresh (30% m.c.)	Closed polycarbonate bottle	Seed Bank (16±2°C, 45%RH)	MC G		37 0	36 0	36	- -				
11	Fresh (30% m.c.)	Closed polythene bag	Seed Bank (16±2°C, 45%RH)	MC G	37 50	44 17	42 67	42 50	43 -				
12	Fresh (30% m.c.)	Closed Polybag in sawdust	Seed Bank (16±2°C, 45%RH)	MC G	34 100	32 83	34 67						

Note : Fresh seeds on sowing resulted 100% germination with initial 36% m.c.

Legend: MC- Moisture content (%), G- germination (%)

Table -15. Vegetative propagation through stem cuttings in *G. farquhariana*

Treatment (ppm)	Rooting (%)	Mean no. of roots (Mean ± SD) (cm)	Mean length of roots (Mean ± SD) (cm)	Survival of ramets (%)
Control	-	-	-	-
IAA 1000	-	-	-	-
IAA 3000	13	1.70 ± 1.43	1.20 ± 1.41	100
IAA 5000	-	-	-	-
IBA 1000	13	1.30 ± 1.32	1.60 ±1.27	100
IBA 3000	33	1.50 ± 0.96	4.90 ± 0.41	100
IBA 5000	75	2.00 ± 1.51	6.31 ± 1.50	100
NAA 1000	13	1.70 ± 0.87	2.00 ± 1.39	100
NAA 3000	-	-	-	-
NAA 5000	-	-	-	-

Table- 16. Vegetative propagation through air layering in *G. farquhariana*

Sl. No.	No. of layers done	Treatment/ Control	Rooting (%)	Survival (%)
1	4	Control	25	100
2	4	IAA 1000	-	-
3	4	IBA 1000	50	100
4	4	NAA 1000	-	100

Plate - 7. *Gymnacranthra farquhariana*

a. Fruiting branch

b. Seeds with aril

c. Seed germination in the nursery

d. Stem rooting success

e. Ring air layering success

f. Planting stock

Plate 8. *Gymnacranthera farquhariana*

Figs. a-b. Views of unloading plants *in situ*

Figs. c-e. Stages of seedling planting *in situ*

Figs. f-g. seedling survival monitoring and metal board display at Kulathupuzha site

4.5. *Knema attenuata* (Hook. f. &Thoms.) Warb.

The populations located and identified for the species are as follows:

Fig. 4. Population sites of *Knema attenuata* identified in the Western Ghats of Kerala

i. Kulamankuzhikudi, N 10° 02′ 43.8″, E 76° 50′ 11.08″ (Neriamangalam Range, Munnar Division), 10km away from Neriamangalam town, enroute Adimali, Alt. 504m. The populations are located in a semi-evergreen secondary type forest patch.

ii. Kulamavu MPCA, N 9° 49′ 14.8″, E 76° 54′ 17.6″ (Nagarampara Range, Kottayam High Range Division) Alt. 867m; the populations are located in the evergreen forests.

iii. Sholayar- Malakkapara, N 10° 18′ 00.8″, E 76°46′ 47.3″ (Sholayar Range, Vazhachal Division). Alt. 850m. The populations are located within the evergreen forests.

iv. Rosemala forest areas lies in N 08° 16′ 9.29″, E 77° 00′ 1.75″ (Shendurney WLS) Alt. 490m. The populations are identified in the evergreen forest.

Propagule collection

The ripe fruits of the species were collected from the populations growing in the evergreen forests at Valera of Neriamangalam Range. The populations are located with a geographical distribution of 10° 0.2' 38.6 " N latitude and 76° 50' 7.9"E longitude at an altitude between 500-550m asl.

Fruits of the species were also harvested from the evergreen forests at Kulamavu MPCA within the Nagarampara Range. The populations are located with a geographical distribution of 9° 49' 14.8" N latitude and 76° 54 ' 17.6"E longitude at an altitude between 700-800m asl.

Seed propagation (Seed storage, Viability and Germination)

The ripe fruits (capsule) are ellipsoid and cuspidate at apex. The fruits and seeds have displayed variations in size in terms average length, diameter and weight (Table- 17).

Table -17. Fruit and seed attributes of *Knema attenuata*

SL No.	Fruit/Seed	Average length	Average diameter	Average weight
1.	Fruit	44.7mm	25mm	14.6g
2.	Seed	23.3mm	14.7mm	3.2g

The processed seeds were subjected for initial Moisture Content (37%) analysis on fresh weight basis and sown germination in the Nursery.

Seeds were also subjected for desiccation and freezing temperature conditions and categorized the seed type.

The fresh seeds with initial moisture content of 37% resulted 83% germination in 28-32 days using river sand as the sowing medium in nursery conditions. The seeds lost viability within 8-10 days during storage in open plastic trays in ambient conditions (control). Critical MC was noted at 21% with 40% germination. The seeds under storage have shown varied viability period viz., 2 months with 30% germination in closed poly carbonate bottle (Ambient), 3 months with 40% germination in polybags contained wet saw dust (Ambient), 5 months with 40% germination in closed polythene bags (Seed bank 20±2°C, 50% RH), 4 months with 17% germination in polybags contained wet saw dust (Seed bank 20±2°C, 50% RH), 3 months with 40% germination in closed poly carbonate bottle (Seed bank 16±2°C,45% RH), 3 months with 32% germination in polybags (Seed bank 16±2°C, 45% RH). However, a maximum period of viability up to 6 months were recorded with 35% germination during storage in closed polycarbonate bottle in controlled seed banking conditions at 20°C ± 50% RH (Table -18). The germination type was hypogeal.

Vegetative propagation

No promising results were recorded for stem cuttings; however in the case of air layering, young stands of 1.5- 2 yrs. old responded positively and rooted within 60-130 days. Layering with IBA at 1000ppm gave 75% success whereas only 50% success noted in the control (Table -19). No promising results were recorded for other auxins. Continuous growth of the plant after separation of air layers from the main stock was obvious.

Planting stock production

A total of 2,700 seedlings of the species were raised in polybags and maintained in the nursery for planting activity as part of the restoration of the species *in situ* (Plate-9).

Enrichment planting (Restoration) and Post restoration Evaluation

Two natural evergreen ecosystems in the Western Ghats of Kerala region were selected for *in-situ* recovery planting.

A total of 2400 seedlings with height ranged from 28-30cm were planted in the natural habitats, *in situ* (Table -20). Further, 300 seedlings were casualty planted in one sites. The seedlings showed slow growth in all the sites. Wilting of seedlings was noticed in the planted areas due to the poor South West monsoon in the planting year.

1. Malakkapara

One thousand and eight hundred seedlings of 1.0-1.5 yrs. old were planted at Chandanthodu near Malakkapara. The mean height of seedlings during planting was 28cm and the maximum height was 51 cm. The seedlings showed 70% survival along with average height of 40cm and maximum height of 64 cm after 1.6 years of planting. The survival of plants was found affected by varied interventions particularly by the Guar and elephant trampling.

2. Kulathupuzha

Six hundred seedlings of 1.0 - 1.5 yrs. old were planted in the evergreen patch at Second Mile. The mean height of seedlings during planting was 23cm and the maximum height was 40cm. The planting of the seedlings was done during the month June 2015. The seedlings showed 85% survival along with average height of 24 cm and a maximum height of 43 cm after 6 month of planting (Plate-10).

Table- 18. Effect of storage condition on the Moisture content and Germination of *Knema attenuata* seeds

Sl. No.	Seed type	Container	Condition/ Temp.	Moisture content / Germination	Moisture content/ Germination (%) after storage(months)						
					1	2	3	4	5	6	7
1	Fresh (37% m.c.)	Open plastic tray	Ambient (25°C, RH-60%)	MC G	-	-	-	-	-	-	-
2	Fresh (37% m.c.)	Closed polycarbonate bottle	Ambient (25°C, RH-60%)	MC G	33 60	30 30	25 0	- -			
3	Fresh (37% m.c.)	Closed polythene bags	Ambient (25°C, RH-60%)	MC G	36 70	33 67	29 40	26 0	- -		
4	Fresh (37% m.c.)	Closed polybag in sawdust	Ambient (25°C, RH-60%)	MC G	26 20	23 0	- -				
5	Fresh (37% m.c.)	Open plastic tray	Seed Bank (20±2°C, 50% RH)	MC G	20 0	18 0	- -				
6	Fresh (37% m.c.)	Closed polycarbonate bottle	Seed Bank (20±2°C, 50% RH)	MC G	35 83	34 100	30 60	29 60	30 40	29 35	23 0
7	Fresh (37% m.c.)	Closed polythene bags	Seed Bank (20±2°C, 50% RH)	MC G	36 70	37 100	35 83	34 60	28 40	24 0	
8	Fresh (37% m.c.)	Closed polybag in sawdust	Seed Bank (20±2°C, 50% RH)	MC G	34 100	30 70	26 34	22 17	16 0		
9	Fresh (37% m.c.)	Open plastic tray	Seed Bank (16±2°C, 45% RH)	MC G	18 0	- -					
10	Fresh (37% m.c.)	Closed polycarbonate bottle	Seed Bank (16±2°C, 45% RH)	MC G	3 80	32 50	30 40	-			
11	Fresh (37% m.c.)	Closed polythene bags	Seed Bank (16±2°C, 45% RH)	MC G	34 70	38 67	32 17	28 0	-		
12	Fresh (37% m.c.)	Closed polybag in sawdust	Seed Bank (16±2°C, 45% RH)	MC G	28 20	20 0	-				

Note : Fresh seeds on sowing resulted 83% germination with initial 37% m.c.
Legend: MC- Moisture content (%), G- Germination (%).

Table -19. Vegetative propagation through air layering in *K. attenuata*

Sl. No.	No. of layers done	Treatment/ Control	Rooting (%)	Survival (%)
1	4	Control	50	100
2	4	IAA 1000	-	-
3	4	IBA 1000	70	100
4	4	NAA 1000	25	100

Plate- 9. *Knema attenuata*

a. Habit

b. Fruiting branch

b. Ripened fruits

d. Processed seeds

e. Seed germination in the nursery

f. Clonal success through ring air layering

g. Planting stock

Plate 10. *Knema attenuata*

Figs. a-b. Views of unloading plants and planting *in situ*

Figs. c-e. Planted seedling, monitoring and metal board displayed at Malakkapara site

Figs. f-h. Seedling planting, monitoring and metal board displayed at Kulathupuzha site

Table -20. Details of enrichment planting (Restoration) and post restoration evaluation in the five wild nutmegs

Sl No.	Name of species	Planting site	Total no. of seedlings planted	Total no. of casualty seedling	Average height increment after 1.5 year (cm)	Survival (%)
1.	***Myristica malabarica***	Sholayar (Anamadamkuthu) N 10° 18' 00.8″ E 076° 46' 47.3″ Elevation : 850 m	3500	150	8-10	70-75
		Kulathupuzha (2nd mile) N 08° 52' 40.2″ E 077° 047' 82.5″ Elevation : 185 m	200	-		
2.	***Myristica beddomei***	Perya (Wayanad MPCA) N 11° 50' 22.1″ E 075° 48' 23.2″ Elevation : 820 m	500	50	6-8	75-80
		Shendurney WLS (Koppam) N 08° 51' 35.9″ E 077° 10' 74.9″ Elevation : 771 m	150	-		
		Shendurney WLS (Thavalakuzhy) N 08° 50' 88.7″ E 077° 10' 58.5″ Elevation : 857 m	150	-		
3.	***Gymnacranthera farquhariana***	Kulathupuzha (Plavuchal and Darbapana swamp) N 08° 52 19.3″ E 077° 05' 03.0″ Elevation : 162 m	2500	350	7-9	65-70
		ResearchWing-Kulathupuzha, Chozhiyakkod	100	-	-	
4.	***Knema attenuata***	Sholayar (Anamadamkuthu) N 10° 18' 00.8″ E 076° 46' 47.3″ Elevation : 850 m	1800	300	6-8	70-75
		Kulathupuzha (2nd mile)	600	-		

		N 08˚ 52' 40.2″ E 077˚ 047' 82.5″ Elevation : 185 m				
5.	***Myristica fatua* var. *magnifica***	Kulathupuzha (Ammayambalam) N 08°50' 20.2" E 077° 02' 11.6" Elevation :154m	250	25	10	75-80
		Kulathupuzha (Perumpadappy) N 08˚ 52' 80.4″ E 077˚ 04' 69.0″ Elevation : 180 m	300	-	12	
		Kulathupuzha (Pullumala) N 08˚ 52' 40.2″ E 077˚ 047' 82.5″ Elevation : 185 m	300	-	13	
		Kulathupuzha (Sasthanada) N 08°49'10.5" E 77°03'04.0" Elevation :156m.	150	25	10	
		ResearchWing, Kulathupuzha Chozhiyakkod	100	-	-	-
	Total seedlings		10,600	900		

Hands on training to the Forest Staff

One day hands on training on 'Nursery practices, plant production and field planting' was imparted to the forest staff upto the level of Range Officers of the three Forest Divisions where restoration of wild nutmeg tree seedlings were carried out (Plate11&12).

Training at North Wayanad Forest Division

The training was imparted to 55 field staff from the Mananthavady, Perya and Begur Forest Ranges on 17 February, 2016 from 10 am to 4 pm at Manathavady Divisional Forest Office. A power point presentation on the topic along with staff interaction was carried out in the forenoon session. The demonstration on Nursery practices were carried out at Social Forestry Nursery at Begur.

Training at Thenmala Information centre

The training was imparted to 75 field staff represented from Thiruvananthapuram, Thenmala Forest Division, Shendurney WLS and Research Wing of the South on 26 February, 2016 from 10 am to 4 pm at Thenmala Information Centre. A power point presentation on the topic along with staff interaction was carried out in the forenoon session. The demonstration on Nursery practices were carried out at Central Nursery, Kulathupuzha.

Training at Vazhachal Information centre

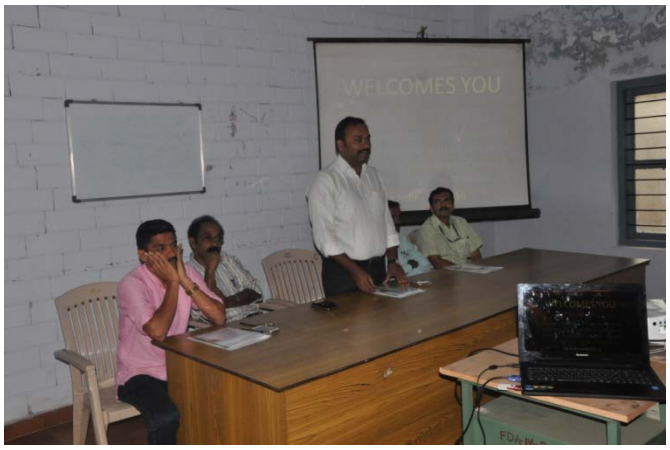
The training was imparted to 53 field staff from the Sholayar, Vazhachal, Athirappilly, Charpa, Kollathirumed Forest Ranges on 29 February, 2016 from 10 am to 4pm at Information centre, Vazhachal**.** A power point presentation on the topic along with staff interaction was carried out in the forenoon session. The demonstration on Nursery practices were carried out in the premises of the Information centre.

Other achievements

Propagation facility created

One polytunnel with mist facility was constructed in the Medicinal plant garden of the Peechi campus for the large scale seed germination and clonal propagation of the five wild nutmeg trees intended for the project. The poly tunnel was also accessed with 15 m long cemented footsteps as the area was sloping downward (Plate-13).

Plate 11. Views of training imparted at different Forest Divisions



North Wayanad Division: Inauguration by DFO, N. Wayanad; Interaction of participants

Shenduruney WL Division: Address by Assistant Wildlife Warden; View of presentation

Vazachal Forest Division : Inauguration by DFO, Vazhachal; View of presentation

Plate 12. Views of training imparted at different Forest Divisions

Social Forestry Nursery at Begur : **Views of Hands -on training**

Central Nursery Kulathupuzha : **Views of Hands -on training**

Forest Information Centre Vazhachal : **Views of Hands- on training**

Plate 13. Views of Nursery facility created

Views of Poly tunnel construction

Poly tunnel - over view

Poly tunnel - inside view

View of poly tunnel along with step access

5. Discussion and Conclusion

The three year study on the wild nutmegs of the Western Ghats, Kerala enabled the identification and mapping of major populations of these species, developed protocols for vegetative propagation, seed storage, germination, large-scale multiplication and management of planting stock in the nursery leading to a strategy for conservation. The augment planting with seedlings has either facilitated the *in situ* enrichment of existing populations or created new populations. Enrichment planting in the identified areas facilitated management of dwindling populations and enhanced natural resources for the sustainable utilization of these species.

The distribution study and mapping revealed that the populations of wild nutmegs are specific to the habitats viz., evergreen, montane and swamp forest ecosystems. Species such as *Myristica malabarica, Knema attenuata* and *Gymnacranthera farquhariana* have been recorded in the evergreen and swamp forests from 150m to 900m asl.; *M. fatua* var. *magnifica* is exclusively distributed in the swamps of lower altitudes. The populations of *M. beddomei* were noted only in montane forests above 800m asl indicating the altitude specificity of the species.

The seed aril of *M. malabarica, M. fatua* var. *magnifica M. beddomei* and *G. farquhariana* are found heavily harvested by local people as a Non

Wood Forest Produce (NWFP). *K. attenuata* is relatively less exploited compared to other wild nutmegs. The natural regeneration of *K. attenuata* was moderately good compared to the other species as exploitation is less for the species. The restricted distribution along with isolated and fragmented populations, specificity of habitat, apart from the existing threats of over exploitation points to the need for conservation of these species as recommended for *Coscinium fenestratum, Dysoxylum malabaricum, Canarium strictum, Persea macrantha* etc. of the Western Ghats (Pandurangan, 2003; Sasidharan *et al.*, 2008).

Though the wild nutmegs have great importance for their ecological and economical values, effective strategies for propagation and germplasm storage for these species are not available and inadequately investigated. Developing protocols for conventional propagation are initial steps for any conservation programme (Pandurangan, 2003; Swarupanandan *et al*., 2013; Jose and Pillai, 2014). The wild nutmegs are generally difficult for cloning through rooting of vegetative cuttings as these species posess tannin and other resinous materials which inhibits the rooting process. However, in juvenile plants of wild nutmegs rooting of stem cuttings and through air layering has been achieved with the aid of auxins with varying levels of success.

The seeds of wild nutmegs are recalcitrant in nature as the seeds are highly sensitive and viability is lost under desiccation and storage in low temperature (King and Roberts, 1979; Hong and Ellis, 1996). Maintenance of Critical Moisture Content (CMC) as part of standardizing ideal storage practices is essential for the germplasm storage of recalcitrant seeds. The storage of seeds in seed banking conditions at 20±2°C and 50% RH was found to be the ideal storage conditions which extended the viability of recalcitrant seeds (Anilkumar *et al*., 1996; 2002; Sabu *et al*., 2008; Jose and Pandurangan, 2013).

The formal and informal methods of conservation programmes have its own pros and cons. And, all these methods are resorted to as part of crisis management with the ultimate objective of sustaining or replenishment of existing populations *in situ*. The restoration of destructed/degraded species is therefore serves to re-establish or rehabilitate damaged or lost plant populations in their native habitats for the conservation and management of existing populations for sustainable utilization of the species. Poor rain fall, wildlife interventions, insect–pest incidences etc. have affected the survival and their growth of the seedlings planted *in situ*. However, post restoration evaluation on the wild nutmegs has shown 70-75% success after 1.6 years of the planting indicating the ability of seedlings to adapt to its native habitats

(Jose, 2001, Decruse *et al*., 2003, Pandurangan, 2003, Gangaprasad *et al.*, 2005, Swarupanandan *et al.*, 2013 Jose and Sumod, 2015). The restoration of wild nutmegs carried out after identifying the sparse populations of these species therefore can be taken as an example of an effective strategy for the conservation of the species, management of dwindling populations/ ecosystems and over all enhancement of natural resources. The success of restoration activity can be inferred only from post-restoration monitoring and evaluation of the survival of the seedlings. The regular monitoring and vigilance of the Forest field staff and involvement of the local people are essential to achieve the envisaged objective of conservation. The hands-on training programme imparted to the field staff encompassing Range Officers to Forest watchers of the Kerala Forest Department were aimed to communicate the need and significance of the present study. The theory cum practical demonstrations given through the training were also of benefit to them to understand the methodology of propagule collection, multiplication, nursery management and restoration practices to be followed for the potential and threatened trees of the Western Ghats. The study can be modeled for other endemic and fast depleting tree resources where ecological restoration becomes major lead in the current day biodiversity action programmes.

6. References

Anilkumar, C., Babu, K.P. and Krishnan, P.N. 2002. Seed storage and viability of *Myristica malabarica* Lam. An endemic species of Southern Western Ghats (India). *Seed, Sci. & Technol.*, 30: 651-657.

Anilkumar, C., Thomas, J. and Pushpangadan, P. 1996. Storage and germination of seeds of *Aporusa lindleyana* (Wight) Baillon, an economically important plant of Western Ghats (India). *Seed Sci. & Technol.*, 25: 1-6.

Bramwell, D. 1991. Botanic Gardens in conservation: Tree introduction into the wild. In: Heywood, V.H. and Jackson, P.S.W. (Eds.). Tropical Botanic Gardens, their role in conservation and development. Academic Press, London.

Decruse, W.S., Gangaprasad, A., Seeni, S. and Menon, S.V. 2003. Micropropagation and ecorestoration of *Vanda spathulata*, an exquisite orchid. *Plant Cell Tiss. Org Cul.,* 72: 199-202.

Gangaprasad A., Decruse, W. S., Seeni, S. and Nair, G.M. 2005. Micropropagation and ecorestoration of *Decalepis arayalpathra* (Joseph & Chandra.) Venter- An endemic and endangered

ethnomedicinal plant of Western Ghats. *Ind. J. Biotech.*, 4: 265-270.

Hong, T.D. and Ellis, R.H. 1996. *Ex-situ* biodiversity conservation by seed storage behaviour. *Seed Sci. and Technol*., 25: 157-161.

IUCN, 2000. The 2000 IUCN Red list of Threatened species, IUCN, Gland.

Jose P.A. and Sumod M. 2015. Enrichment planting and *ex situ* conservation of *Drypetes malabarica* and *Hydnocarpus macrocarpa* - two endemic and endangered trees of Southern Western Ghats. In: C. Buvaneswaran *et al*., (eds), *Advances in Tree Seed Science and Silviculture.* Institute of Forest Genetics and Tree Breeding, Coimbatore. pp. 270-274

Jose, P.A and Pillai, C.P.K. 2014. Conservation through restoration of two endemic endangered trees of Western Ghats of Kerala. Final Project Report No. 473. Kerala Forest Research Institute, Peechi.

Jose, P.A. Pandurangan A.G. and Hussain A. 2011. Effect of auxins on clonal propagation of *Gluta travancorica* Bedd. - an endemic tree of Southern Western Ghats. *Ind. J. For.*, 34 (1): 85-88.

Jose, P.A. 2001. A Study on the Population structure, Dynamics and Conservation of Two Rare and Endemic Trees of Western Ghats

of Kerala. Ph.D. Thesis, Kerala University, Thiruvananthapuram. pp. 184.

Jose, P.A. and Pandurangan, A.G. 2013. Seed storage studies on *Gluta travancorica* Bedd. – An endemic and threatened tree of Southern Western Ghats. *Ind. J. of For.*, 36(3): 349-352.

Jose, P.A. and Thomas, J. 1998. An account of the vegetative propagation in *Terminalia chebula* Retz. *Ind. For.*, 124(5): 357-359.

Jose, P.A., Hussain, K.H. and Sreekumar, V.B. 2014. Developing an information system for the Rare, Endangered and Threatened (RET) plants of Southern Western Ghats. KFRI Research Report No. 492. Kerala Forest Research Institute, Peechi.

Jose, P.A., Pandurangan A.G. and Hussain A. 2009. Clonal propagation of *Coscinium fenestratum* (Gaertn.) Colebr. – A critically endangered medicinal plant of Western Ghats. *Journal of Non- Timb. For. Prod.*, 16(4): 295-298.

Jose, P.A., Swaruapanandan, K. and Pandalai, R.C. 2011. Restoration of *Dipterocarpus bourdillonii* and *Humboldtia bourdllonii*, two critically Endangered Trees of Western Ghats. *Evergreen*,No. 65-66 Half-yearly Newsletter of Kerala Forest Research Institute, Peechi.

Jose, P.A., Thomas J. and Krishnan, P.N. 1995. Vegetative propagation of *Ochreinauclea missionis* (Wall. ex G. Don) Ridsd. : A rare and threatened tree species of Western Ghats. *Ind. For*., 121(12): 1159-1164.

King, M.W. and Roberts, E.H. 1979. The storage of recalcitrant seeds: Achievements and possible approaches. International Board for Plant Genetic Resources, Rome.

Pandurangan, A.G. 2003. Rescue and Restoration of endemic and RET medicinal plants of Agasthyamalai, Kulamavu and Wayanad MPCAs, Kerala, India. Final Project Report. Tropical Botanic Garden and Research Institute, Thiruvananthapuram.

Roy, R.K., and Datta, S.K. 2003. The Role of Botanic Gardens in the conservation of plants. In: M.K. Janarthanan and D. Narasimhan (eds.), *Plant Taxonomy, Human Welfare and Conservation*, Goa University. pp. 345-351.

Sabu,T., Anilkumar, C., Sham A. Nabeesa Salim, Louis Jesudass L., Mohanan, N., and Krishnan, P.N. 2008. Seed maturity, germination and storage studies on an endemic tree - *Humboldtia decurrens* Bedd.ex Oliver. *Ind. For*., 134(2) : 203-211.

Sabu,T., Louis Jesudass L., Nazarudeen A. and Sham A. 2006. Effect of auxins on the rooting of *Humboldtia decurrens* (Caesalpiniaceae), a rare, endemic tree from the Western Ghats of India. *Ind. J. of Bot. Res*., 2(2) : 201-204.

Sasidharan, N. 2011. Flowering Plants of Kerala Ver.2. Kerala Forest Research Institute, Peechi, Thrissur.

Sasidharan, N., Sivaram, M., and Muraleedharan, P.K. 2008. Quantitative inventory of Non- Wood Forest Products in Northern Kerala. KFRI Research Report, No. 306, Kerala Forest Research Institute, Peechi, Thrissur. pp.435.

Sharma, J.K. 2003. Forest resources of the Kerala part of Western Ghats. In: Mohan Kumar, B., Nammer, P.O. and Luckins C. Babu (Eds.). Papers of the training workshop on Natural Resource Management: Changing scenarios and shifting paradigms. Kerala Agricultural University, College of Forestry, Thrissur. pp.1-8.

Sharma, K., Thakur, S., Badiyala, S.D. and Sharma, N.K. 1995. First report on the propagation of *Terminalia chebula* Retz. Through patch budding. *Ind. For*., 121(8): 760-761.

Swarupanandan, K., Indira, E.P., Muralidharan, E.M., Pandalai, R.C., Jose, P.A. and Sanjappa, M. 2013. Species recovery of

Dipterocarpus bourdillonii and *Humboldtia bourdillonii*, two critically endangered endemic trees of Western Ghats. Final Project Report No. 463. Kerala Forest Research Institute, Peechi.

Vijayakumaran Nair, P., Ramachandran, K. K., Swarupanandan, K. and Thomas P. Thomas. (2007). Mapping biodiversity of the *Myristica* Swamps in Southern Kerala. KFRI Research Report, No. 326. Kerala Forest Research Institute, Peechi, Kerala. pp.227.