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CONSERVATION THROUGH RESTORATION OF TWO ENDEMIC ENDANGERED TREES OF WESTERN GHATS OF KERALA

P.A. Jose
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Kerala Forest Research Institute

Peechi Thrissur- 680653

January 2014

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Cover page

Left top : ***Drypetes malabarica*- Infructescence**
Left bottom : ***Drypetes malabarica*- Habit**
Right top : ***Hydnocarpus macrocarpa*- Bisexual flower**
Right bottom : ***Hydnocarpus macrocarpa*- Habit showing fruits**

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PROJECT PARTICULARS

1.	Title of the project	:	Conservation through restoration of two endemic endangered trees of Western Ghats of Kerala
2.	Department/Organization implementing the project	:	Kerala Forest Research Institute, Peechi.
3.	Special Area of study	:	i. Population structure ii. Population dynamics (Vegetative and Reproductive dynamics) iii. Climatic and Edaphic factors analysis iv. Conservation Strategies (Vegetative and Seed biological studies) v. Restoration and post restoration evaluation
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Abstract

Owing to the importance and significance of conservation and management of Rare, Endangered and Threatened (RET) plants of the Western Ghats, in 2010, a three year study on the conservation through restoration of two endemic and endangered trees of Southern Western Ghats were conducted by receiving Plan grant of the Kerala Forest Research Institute (KFRI), Peechi.

The species studied are *Drypetes malabarica* (Fam. Euphorbiaceae) and *Hydnocarpus macrocarpa* (Fam. Flacourtiaceae). *D. malabarica* is a medium sized evergreen tree having patchy and isolated populations in Kerala and Tamil Nadu. The species was so far been unattended for any kind of studies and at the same time had prioritized for conservation by the IUCN. The wood was used by the local people for construction purpose and ripened fruits were food resource for various wildlife. Natural regeneration of the species was meager in its habitats. *H. macrocarpa* is another medium sized evergreen tree is also with fragmented and isolated populations in Kerala and Tamil Nadu. The matured fruits were overexploited by the local people for seeds as a Non Wood Forest Produce (NWFP) of industrial applications and therefore affected the natural regeneration drastically in its habitats. By considering the small size in populations and fewness in distribution nature, IUCN was categorized the species under Endangered for priority conservation efforts. Thus the present study was initiated with the objectives: (i) To study the population structure, diversity, dynamics including environmental factors and phenology of the two species.

(ii) To evolve suitable methods of conventional propagation and multiplication and to restore the species in their natural habitats by augmented seedling planting.

Population ecological, reproductive phenological, climatic and edaphical, propagation and restoration aspects were attempted of the two species. Distribution of the species was studied through intense field explorations. Phytosociological studies were conducted in quadrats of 33x33m^2 plot sizes with a total enumeration ranging from 5445-7623 m^2 for each species and arrived the Importance Value Index (IVI) of the species in respective ecosystems. Reproductive phenology was studied by periodic field visits and observations on different phenophases. Reproductive biological studies included anthesis, pollen fertility, P:O ratio, Sigma receptivity and identification of insect-pest associated. Propagation of the species through seeds, rooting of stem cuttings, air layering was attempted. The propagated seedlings/ ramets were augment planted *in situ* as well as *ex situ* sites and their survival and growth performance evaluated at 6-month intervals for a period of 1.5 year.

The populations of *D. malabarica* were highly fragmented in nature and noticed in certain forest areas in Kerala. The moderately high altitude and habitat preference in adjacent water course along with unique association of tree species in the ecosystems were found integral for the biological functions of the species. The moderately lower number in pre reproductive individuals, lower dominant nature among associates was adding elements towards the rare occurrence of the species in the forest communities.

The species diversity analysis of *D. malabarica* in each site (five quadrats of each sized 33x33m^2 covering a total enumerated area of 5445m^2 per site) has exhibited comparatively lower dominant nature of the *D.malabarica* among the associates in different sites. In Neriamangalam, out of 57 species enumerated in five quadrats, the species attained with 13th relative position among associates. Further, the area of occurrence of the species has calculated into 3km^2 and area of occupancy into 0.0036 km^2 along with 50 mature individuals in the particular forest segment. Similarly at Malakkapara, out of 69 species enumerated in five quadrats, the species attained with 11th relative position among its associated species. The area of occurrence of the species has calculated into 30km^2 and area of occupancy into 0.011 km^2 along with 150 mature individuals in the particular forest segment. Whereas, at Shenduruny, among 63 associated species identified, the species reaches at 26th relative position. The area of occurrence has calculated into 75km^2 and area of occupancy into 0.0047 km^2 along with 65 mature individuals in the particular forest segment. At Kulamavu MPCA, among 54 associated species, the species attained with 11th relative position. Further, the area of occurrence of the species has calculated into 1.7km^2 and area of occupancy into 0.015 km^2 with 200 mature individuals within the MPCA. The aggregation in area of occurrence and area occupancy of the species in four study sites thus revealed an extent of species in 110km^2 with 465 mature individuals under area of occupancy within 0.0343km^2. These values are found falling under 'Endangered' (EN) category of IUCN wherein the extent of species had given @ 5000km^2 with less than 2500 mature individuals under an area of occupancy of 500km^2.

The flower wilting/falling during pollination period, underdeveloped/ aborted ovules in the ovary, short period in stigma receptivity, low pollen count/ ovule etc. suggest the pre or post fertilization complexities in the species. The insect- pest incidence in matured fruits, high level of aerial and ground level predation of ripened fruits were drastically reduced the natural regeneration and accelerated the rarity of the species in their habitats.

A significant observation was that a moderate level of auxin concentration of NAA 3000 ppm was found best rooting performance (100%), compared to lower and higher concentrations (1000 and 5000ppm). Whereas, Control set resulted only with 10-15% success only. In air layering, the auxins generally showed positive effect in rooting. A moderate level of auxin concentration such as IAA and IBA at 1000ppm and NAA at 3000ppm had resulted maximum rooting success (100%).

Seeds with initial moisture content of 46% lose its viability within two weeks at a Critical Moisture Content (CMC) level of 28-30% and were sensitive and shed viability during storage in lower temperature due to its intermediate seed type behaviour.

A total of 400 seedlings were reintroduced in four natural habitats (*in situ*) and 150 seedlings in three *ex situ*. The results were promising and supported for the enhancement of existing genetic stock and creation of alternate field banks for the species. Out of the four *in situ* areas where seedling planting done, 75-80% seedling survival along with 4-7 cm height

increment was recorded within 1.5 years of planting. Out of 6 *in situ* areas where seedling planting done for *H. macrocarpa,* 40-70% seedling survival along with 3-23 cm height increment was noticed within 1.5 years of seedling planting. Whereas, the seedling survival in *ex situ* was fairly better for both the species and noted @ 70-98% along with 3-6 cm height increment for *D. malabarica* and 80-94% along with 4-30 cm height increment within 1.5 years of seedling planting.

The populations of *H.macrocarpa* were also highly fragmented and confined to certain forest areas in Kerala. The moderately high altitude and habitat preference in adjacent water course along with unique association of tree species in the ecosystems found support for the biological functions of the species. The moderately lower number in pre reproductive individuals, lower dominant nature among associates was promoting the rare occurrence of the species in forest communities.

The species diversity analysis of *H. macrocarpa* at Malakkapara (5 quadrats, each sized of 30mx30m covering, a total enumerated area of 5445m^2) and 7 quadrats at Neriamangalam covering an enumerated area of 7623m^2 has shown moderately lower dominant nature among the associates. At, Malakkapara, out of 41 species enumerated in five quadrats, *H. macrocarpa* attained with 11th position. Further, the area of occurrence of the species has calculated into 12 km^2 with an area of occupancy, 0.0045km^2 covering mature individuals of 55 numbers in the particular forest segment. Similarly, at Neriamangalam, out of 81 species enumerated in 7 quadrats, *H.*

macrocarpa attained with 11th position among the associates. The area of occurrence has calculated into 3 km^2 with an area of occupancy of 0.012 km^2 with 150 mature individuals in the particular forest. The aggregation in area of occurrence and area of occupancy of the species in two study sites thus revealed an extent of species in 15 km^2 with 205 mature individuals under area of occupancy of 0.0165km^2. These values are falling under Critically Endangered (CR) category of IUCN wherein the extent of species is less than 100km^2 and with less than 250 mature individuals under an area of occupancy of below 10km^2.

The flower wilting/falling during pollination period, short period in stigma receptivity, immature fruit fall etc. pointing towards the biological complexities associated with the species. The aerial and ground level seed predation, lack of efficient fruit dispersal methods etc. was limited the natural regeneration and confinement the populations in certain micro habitats. The overexploitation of matured fruits/ seeds as NWFP were heavily reduced the soil seed and seedling bank which in turn accelerated the rarity process as a continuing phenomenon in the species.

A moderately higher concentration of auxin (IBA 5000ppm) had resulted better stem rooting (66%) compared to control (30-35%). But during air layering, moderate auxin concentration (NAA 3000ppm) had resulted maximum success (100%).

The seeds were recalcitrant and therefore found sensitive towards both desiccation and chilling storage conditions. Seeds with initial moisture content of 45% lose its viability within one

week at CMC level of 16-17%. However, seeds enabled for storage more than two months in the closed poly carbonate bottles kept at seed bank conditions maintained at 20°C and 40% RH.

Out of 6 *in situ* areas where seedling planting done for *H. macrocarpa,* 40-70% seedling survival along with 3-23 cm height increment was noticed within 1.5 years of seedling planting. But the seedling survival in *ex situ* conditions was fairly better for both the species and noted @ 70-98% along with 3-6 cm height increment for *D. malabarica* and 80-94% along with 4-30 cm height increment within 1.5 years of seedling planting.

1. Introduction

The Western Ghats is one among the ecologically richest regions of India. The Western Ghats comes next to the Himalayas in the diversity of biological species (Gadgil, 1984). Its singular geological history, and the relatively limited width of the hill ranges which are separated by narrow passes, have contributed to a high degree of endemism (Ahmedullah and Nayar, 1987; Nayar, 1996). The Western Ghats is also recognized as the centre of origin of several cultivated plants and gene centre for several orchid species. The Western Ghats also has a high percentage of medicinal plants. The Western Ghats is one of the 34 hotspots in the planet and supports 27% of the flowering plants of the Indian sub continent, of which, 1,500 are endemics. The southern part which corresponds to Travancore and the hills south of Palghat gap consists higher number of endemic tree species of the Western Ghats. Depending upon the amount of rainfall, soil type and climate, different vegetation types have been formed along the Western Ghats. The dominant vegetation types are West coast tropical evergreen forests, West coast semi-evergreen forests, Southern moist mixed deciduous forests, Southern dry mixed deciduous forests and Scrub jungles (Champion and Seth, 1968). Concomitantly, the area faces high degree of threat which affects diverse biota as well as the functioning of various species/ ecosystems it possesses.

Western Ghats of Kerala covers about 9400 km^2, of which 24 percent has been declared as Protected Areas by establishing Sanctuaries and National Parks for the conservation of rare and endangered plants and animals. It is estimated that about 27

percent of the area of Kerala state is under forest cover. The current decline in biodiversity is largely due to the result of human activity. The loss of the world's biological diversity mainly stems from habitat destruction, over-harvesting, pollution and inappropriate introduction of foreign plants and animals.

The populations of species having few individuals are more vulnerable to extinction. They are also more likely to experience genetic drift and inbreeding. (Fischer and Matthies, 1998; Keller and Waller, 2002). The ultimate result of a dwindling population and gene pool is extinction of the species. Within the natural process, two kinds of populations and situations led to extinction. In the first situation, opportunistic species invade new territories in different environments. These opportunistic species generally establish in the new habitat rapidly to utilize available resources efficiently. They are naturally short-lived with life spans usually less than one year, and they produce numerous offsprings that are disseminated over a wide area. In the second kind of extinction, large population exists in a stable environment, but at the maximum capacity the habitat can provide. These species tend to occupy the areas for many years on a continuous basis and individuals themselves may have relatively long life spans (Knees, 1990). Depending up on rarity (in terms of the population size) and a posited higher risk for extinction, the endemics constitute nine various categories by IUCN, viz., Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT) etc.

Many of the endemic and RET plant species are either medicinal or economic importance and therefore pressure to

exploit these plants increased many fold. Tragically, endemics once lost, can never be replaced or regenerated. It is also predicted that by the time the population of India stabilizes approximately by 2025 AD, one fifth of our species would be on the way out or would become extinct. Therefore, it is high time to necessitate immediate action for protection and conservation of endemic and threatened plants on a priority basis (Nayar, 1996). Much often, the process of rarity stems from the ecological and biological aspects of the species (Reveal, 1981). Therefore, to understand factors responsible for the rarity of a species, a detailed knowledge of population structure, population dynamics along with the analysis of climatic and edaphic factors in its original habitat is inevitable.

The associate species in the community, relative dominance of each species, spatial and stratic distribution and the size of the population in general are the integral elements related to the study (Pascal, 1988; Pandurangan, 2003). Studies on the floral biology help in understanding the breeding behaviour and reproductive biology of the species. This includes flowering features, pollination, anthesis, pollen viability and fertility, stigmatic receptivity, pollen ovule ratio, rate of fertilization, etc. The dispersal and regeneration mechanism along with habitat conditions are of significant episodes regarding the dynamics of the species. Insects and pests are other determining factors on the population behaviuor of the species. Defoliators, leaf and floral eaters, fruit and seed borers, etc. are the major threats to the species distribution and survival (Pushpangadan, 1992).

On the basis of rarity and threatened species composition, the southern Western Ghats consists around 1,100 flowering species under Rare, Endangered and Threatened (RET) categories (Unpublished) among which 495 species are recorded from the Kerala and this covers 151 species of trees (Sasidharan, 2003). The major causes of plant rarity have been globally identified and are often associated with ecology and biology of the species which finally lead to the endangerment of the species. Efforts like species recovery studies are therefore needed urgently to conserve and maintain genes, species and ecosystems along with sustainable use of biological resources.

In this context, the present study was proposed to assess the extinction risks faced by two endemic and RET tree species of southern Western Ghats viz., *Drypetes malabarica* and *Hydnocarpus macrocarpa* by studying the population structure, population dynamics along with the analysis of climatic and edaphic factors *in situ*. In addition, development of conservation strategies such as standardization of clonal propagation methods, ideal seed storage practices and raising of planting stock as the outcome of propagation and multiplication studies are envisaged. Restoration through augmented seedling planting *in situ* and alternate genetic stock development *ex situ* and evaluation on post restoration seedling success is also proposed.

2. Objectives

i. To study the population structure, diversity, dynamics including environmental factors and phenology of the two

species (*Drypetes malabarica* (Bedd.) Airy Shaw and *Hydnocarpus macrocarpa* (Bedd.) Warb.

ii. To evolve suitable methods of conventional propagation and subsequent multiplication of the above two species and to restore the same in their natural habitats by augmented seedling planting.

3. Study area

The study areas were selected after referring species literature from district floras, herbaria and other leading publications. In addition, the field experiences of the investigators were also immensely supported to locate the sites.

3.1. Population sites of *Drypetes malabarica*

The populations of the *Drypets malabarica* were located in:

1. Kulamankuzhikudi, N 10^0 02′ 43.8″L, E 76^0 50′ 11.08″ L. (Neriamangalam Range, Munnar Division), 10 km away from Neriamangalam town, towards Adimali, Alt. 504m; The populations are located in a semi-evergreen secondary type forest patch.

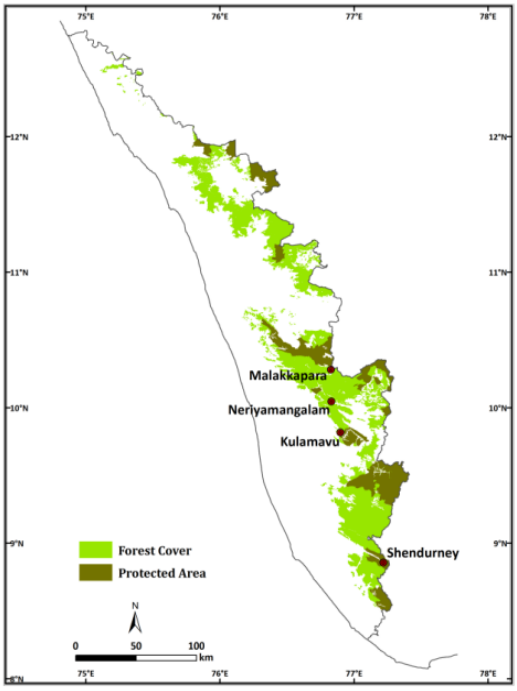

Fig.1: Population sites of *Drypetes malabarica* in Western Ghats of Kerala

The area is surrounded by human settlements and was subjected to encroachment, grazing of domestic animals, illegal firewood collection etc. Despite varied disturbances, this location documented large number of mature individuals.

2. Kulamavu MPCA (Medicinal Plant Conservation Area) N 9^0 49′ 14.8″ L, E 76^0 54′ 17.6″ (Nagarampara Range, Kotayam Division) Alt. 867m; the populations are located in the evergreen forests and disturbance rate is much lower.

3. Sholayar- Malakkapara, N 10^0 16′ 43.1″, E 76^0 50′ 56.6″ (Sholayar Range, Vazhachal Division) Alt. 849m. The populations are located within the evergreen forests and disturbance rate is also minimum.

4. Rosemala forest areas lies in N^0 08 16′ 9.29″ L, E 77^0 00′ 1.75″ (Shendurny WLS) Alt. 490m. The populations are identified in the evergreen forest and disturbance is poor. (Fig.1).

3.2. Population sites of *Hydnocarpus macrocarpa*

The populations of the *Hydnocarpus macrocarpa* are located in 1. Kulamankuzhikudi, N 10^0 02′ 43.8″L, E 76^0 50′ 11.08″ L. (Neriamangalam Range, Munnar Division), 10 km away from Neriamangalam town, towards Adimali Town, Alt. 565m.

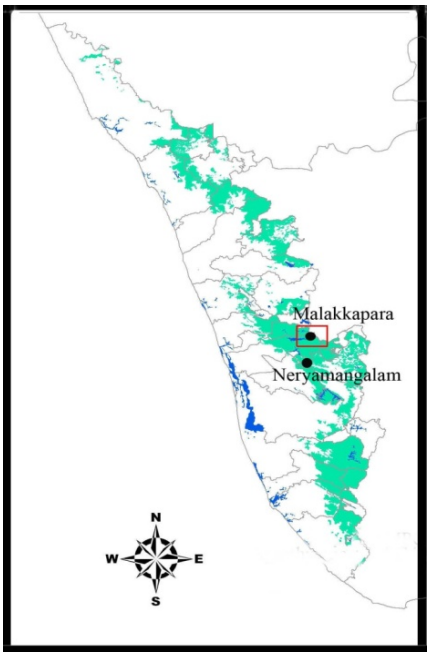

Fig.2: Population sites of *Hydnocarpus macrocarpa* in Western Ghats of Kerala

The populations are located in a semi evergreen secondary type forest patch. The area is surrounded by human settlements and subject to encroachment, grazing by domestic animals, illegal firewood collection etc. Despite the disturbances, this location documented large number of mature individuals of the species.

2. Sholayar- Malakkapara forests lies in N 10^0 16′ 43.1″, E 76^0 50′ 56.6″ (Sholayar Range, Vazhachal Division) Alt.843m (Fig. 2). The populations are located within the evergreen forests and disturbance rate is minimum.

Also located a small population of the species at Kallar Forests (Palode Range, Thiruvananthapuram Division) Alt. 500m. The phenological observations of the species were carried out as an alternate site of the species.

4. Materials and Methods

4.1. Materials

Drypetes malabarica (Bedd.) Airy Shaw (Euphorbiaceae) and *Hydnocarpus macrocarpa* (Bedd.) Warb. (Flacourtiaceae) are the two endemic, endangered and economically important tree species selected for the study.

4.1.1. Species description

Drypetes malabarica (Bedd.) Airy Shaw, Kew Bull. 23: 56. 1969; Chandrab. in A. N. Henry *et al.*, Fl. Tamil Nadu Ser. I. Analy. 2: 226. 1987; M. Mohanan & Henry, Fl. Thiruvanthapuram 413. 1994; Sasidh. & Sivar., Fl. Pl. Thrissur

For. 401. 1996; Sasidh., Fl. Shenduruny WLS 286. 1997; Sasidh., Fl. Periyar Tiger Reserve 370. 1998; Chakrab. *et al.*, Journ. Econ. Tax. Bot. 21: 269. 1997; Gopalan & Henry, Endemic Pl. Agasthiyamala 142. 2000; Sasidh., Fl. Parambikulam WLS 287. 2002. *Cyclostemon malabaricus* Bedd., Fl. Sylv. For. Man. Bot. 199. 1873 and Icon. Pl. Ind. Or. 41, t. 183. 1874; Hook. f., Fl. Brit. India 5:341.1887; Gamble, Fl. Pres. Madras 1302. 1925 (2: 911. 1957 repr. ed.).

Trees, 10-15 m tall, rarely extend to 25-30 m height; branchlets angular, brown tomentose, terete, 2-5 mm thick Leaves alternate, simple; stipules ca 1 cm long, linear, pilose; petioles up to 1 cm long, grooved adaxially, pilose; lamina, 10-25 x 3-7.5 cm, oblong, coriaceous, pilose beneath, glabrous above, greenish brown when dry, oblique (acute on one side, rounded on other) at base, entire, abruptly acuminate (acuminate up to 2 cm long) at apex, penninerved; midrib raised beneath, more pilose on both surfaces, obscure and grooved above; nerves 6-10 pairs, prominent beneath, obscure above. Inflorescence cauliflorus, in clusters; pedicels 0.5-1.9 cm, brownish yellow tomentum.

Male flowers: pedicels 0.5-0.6 cm long, pilose; sepals 4, sub orbicular, 0.4-0.5 x 0.35-0.4 cm, densely ochraceous-villous; stamens 0.3-0.4, 0.5-0.7 cm long; anthers oblong, ca 0.015 cm long; disk discoid, pubescent.

Female flowers: pedicels up to 1.9 cm long, pilose; sepals as in male flowers; ovary 2-loculed; ovules 2 in each locule; style very short or 0; stigmas 2, dilated, reniform or ellipsoid. Fruits

subglobose-ovoid or oblong, ca 2.25 cm across, bilocular, thick-walled, fulvous tomentulous; fruiting pedicels ca 1 cm long. Seeds ovoid, ca 0.2 x 0.2 cm, solitary in each locule, pendulous, smooth, minutely bilobed or notched at posterior end.

Tree is locally known as Kalladamba and Kaduvapudukkan. The species has an Endangered status (IUCN, 2000; Sasidharan, 2004; 2011). The medium sized tree inhabits the evergreen forests at altitude between 500-1500m. The tree is endemic to Kerala and Tamil Nadu along the Southern Western Ghats. The wood is moderately hard and used locally. Apart from the floristic documentations and limited herbarium representations, practically no study has so far been reported to the species.

Hydnocarpus macrocarpa (Bedd.) Warb. in Engl. & Prantl, Naturl. Pflanzenfam. 3(6a): 21. 1893; R.L. Mitra in B.D. Sharma & N.P. Balakr., Fl. India 2: 421. 1993; M. Monahan & Henry, Fl. Thiruvananthapuram 61. 1994; Sasidh. & Sivar. Fl. Pl. Thrissur For. 45. 1996; Sasidh., Fl. Shenduruny WLS 27. 1997; Sivar. & Mathew, Fl. Nilambur 59. 1997; Ravikumar & Ved, Illustr. Field Guide 100 Red Listed Med. Pl. 199. 2000. *Asteriastigma macrocarpa* Bedd., For. Man. Bot. t. 266. 1873 & Ic. t. 242. 1868-1874; Gamble, Fl. Pres. Madras 52(38). 1915. *Taraktogenos macrocarpa* (Bedd.) Balakr. Journ. Bombay Nat. Hist. Soc. 67: 57. 1970.

Trees, to 25 m tall; outer bark light brownish grey with aromatic cyanide-like smell; inner bark ca 0.5 cm thick, pale purple pink. Leaves alternate, oblong– lanceolate to oblanceolate,

acute to shortly rounded at base, entire, rounded and abruptly caudate- acuminate at apex, 15-20 x 7-10 cm, coriaceous, dark, shining, green above; lateral nerves 6-8 pairs, arched, distinct above, raised and prominent beneath; tertiary nerves sub parallel and reticulations prominent beneath. Flowers polygamous, ca 2.5 cm across, in fascicles in leaf axils, leafless twigs or on old wood, greenish white, foetid petals shorter than sepals, ciliate, with 3-lobed scales at base inside. Stamens numerous, many-seriate. Ovary with many ovules on 6 or 7 parietal placenta and as many large sessile 2-lobed stigmas. Fruits globose, 12-16 cm, woody, dark brown; seeds many, oblong, angled, 3-3.5 x 2-2.5 cm, dark brown, embed in pulp.

Tree is locally known as Mala-marotti and Vella-nanku. The species has Endangered and Vulnerable status as per different authors (IUCN, 2000; Sasidharan, 2004; 2011). It is a moderate sized tree found distributed in areas adjacent the water course in evergreen forests at altitude between 500-900m. The tree is economically important for its medicinal and industrial values. The tree is endemic to Kerala and Tamil Nadu along the Southern Western Ghats. The species is also hardly attended for ecological and conservational studies.

4.2. Methods

The entire research programme has been divided into 5 tasks for operational reasons and they are discussed here under.

4.2.1. Population structure

The sampling quadrat size was worked out as per species area curve method to determine the vertical, horizontal, age wise distribution and crown projections of candidate species as well as associations in a community. Populations of the two species were studied in releves (sample plots) of 0.1 ha (33m x 33m) size. All trees having girth at breast height (gbh) ≥30cm in the study plots were identified, enumerated and recorded (Swarupanandan *et al*, 2013). Each candidate species was enumerated in quadrats ranging 5445-7623 m^2 according to their availability within the forest areas in order to reach a realistic conclusion on the relative abundance of the species in a community. The floristic diversity in terms of relative frequency, relative density, relative dominance and IVI were calculated (Misra, 1968 and Sivaram *et al.*, 2006). The Area of occurrence and area of occupancy were estimated as per IUCN norms. The mature individuals were physically counted in the sampled and non sampled areas.

Density: Number of individuals of a species per unit area gives its density (d). This is usually computed as trees per hectare (tr ha^{-1}).

Frequency: The chance of finding a species in a particular area in a particular trial sample is called its frequency (f) and is expressed as the number of quadrats in which a species is found per total number of quadrats studies.

Dominance (Basal area): Cover is usually the area covered by crown or shoot area, or the stem. For trees and shrubs, the

area occupied by the stem is taken as the cover and is known as the basal area. Basal area= πr^2, r= gbh/2π.

The *Importance Value Index* (IVI): It is defined as the sum of Relative Density (rd), Relative Frequency (rf) and Relative Dominance (rD) (Muller-Dombois and Ellenberg, 1974). This expresses the relative importance of the species in the community. Thus, IVI = rd + rf + rD, where,

rd = (Density of the species) / (Density of the stand)

rf = (Frequency of the species) / ∑ (frequency of all the species)

rD = (Basal area of the species) / (Basal area of all species)

Strata were classified as per the height stands. Girth size was used to determine the age wise distribution. Populations were categorized into set of future, set of present and set of past depending upon the reproductive nature of the species. Crown projections were measured by four perpendicular radii of the tallest individuals of the species in the quadrat (Pascal, 1988; Parthasarathi and Sethi, 1997).

Extent of occurrence is the extent of distribution of a species within the shortest continuous imaginary boundary of the species.

Area of occupancy is the area occupied by the species within its extent of occurrence wherein the species satisfy its survival.

4.2.2. Population Dynamics

It covers both vegetative and reproductive stages of the species in their natural life cycle (Davy and Jefferies, 1981). Observations on vegetative dynamics were made for leaf initiation, growth, maturity, senescence and insect-pest associations. In reproductive dynamics, different episodes such as flowering, fruiting, seedlings including insect-pest, dispersal and regeneration phases were monitored and recorded. (Murali and Sukumar, 1994; Daniel and Jayanthi, 1996; Vivek Menon, 2003; Jose *et al.,* 2000; Jose and Pandurangan, 2002; Jose *et al.,* 2003, 2004).

4.2.3. Climatic and Edaphic Factors

The climatological data of the species covering atmosphere temperature (day and night -^{0}C) and atmospheric humidity (night - %) in three prominent seasons of a year (summer, monsoon and winter) were recorded and average values taken for representation.

The edaphological data on soil texture (from three soil depth levels such as surface, 15cm deep as middle and 30 cm deep as bottom), P^H, major macro nutrients such as N, P and K; soil moisture content and temperature in three seasons of a year were recorded and average values represented (Bawa, 1983; Gupta and Malik, 1996).

4.2.4. Conservation strategies

The infrastructural facilities such as two Low polytunnels with mist irrigation and Shade house were constructed for the large scale propagation, multiplication and establishment of seedlings in the nursery. Conventional rooting of stem cuttings through application of hormones, air layerings and seed germination studies were experimented with.

4.2.4.1. Vegetative propagation

Hormones were used to induce roots in stem cuttings. Stem cuttings along with auxins such as IAA, IBA and NAA of different concentrations such as 1000, 2000, 3000, 4000, 5000 ppm etc. were attempted. Similarly, air layering experiment was done along with in different contcentrations of IAA, IBA and NAA (Jose *et al.*, 1995; Jose and Thomas, 1998; Sharma *et al.*, 1995).

4.2.4.2. Seed biological studies

The seed collection, processing in relation to moisture content, storage, germination, extension of viability in different storage conditions were studied as part of longterm germplasm conservation of the species. Dormancy behaviour of the seeds was also analysed with appropriate physical and chemical treatments in order to enhance germination (Hong and Ellis, 1996; Hong and Ellis, 1998; Jose and Pandurangan, 2002; Jose and Pandurangan, 2011; Kamarudeenkunju, 2003)

4.2.5. Restoration

The propagules raised as byproduct of propagation and multiplication studies were used to implement the restoration of the species. Both *in situ* and *ex situ* planting of the species were carried out to ensure the survival of seedlings (Groombridge, 1992; Truman, 2000). The survival of planted seedlings in each site was monitored at 6 months intervals after planting. The height increments of each seedling were also taken during each visit. 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.

5. Results

5.1. *Drypetes malabarica*

5.1.1. Population structure

The population structure and floristic diversity analysis in the four study areas viz., **Neriamangalam, Malakkapara, Shenduruney WLS** and **Kulamavu MPCA** are detailed below.

i. Neriamangalam

The vegetation profile (Vertical) of the population located at Neriamangalam showed the occurrence of major tree species apart from *Drypetes malabarica* (Bedd.) Airy Shaw, such as *Elaeocarpus tuberculatus* Roxb., *Poeciloneuron indicum* Bedd.,

Vateria indica L , *Holigarna grahamii* (Wight) Kurz, *Bischofia javanica* Blume, *Palaquim ellipticum* (Dalz.) Baill. and *Dysoxylum malabaricum* Bedd. ex Hiern as first layer/storey, reaching a height range of 31-40 m. The second storey represented by *Drypetes malabarica* (Bedd.), *Hydnocarpus macrocarpa* (Bedd.) Warb., *Knema attenuata* (Hook. f. & Thoms.) Warb., *Mesua thwaitesii* Planch. & Triana, *Paracroton pendulus* (Hassk.) Miq. *ssp. zeylanicus (Thw.) Balakr. & Chakrab., Vateria indica* L, *Dysoxylum malabaricum* Bedd., *Otonephilium stipulaceum* (Bedd.) Radlk., *Macaranga peltata* (Roxb.) Muell.-Arg., *Turpinia malabarica* Gamble, *Mallotus tetracoccus* (Roxb.) Kurz, *Mastixia arborea* (Wight) Bedd., *Walsura trifolia* (A. Juss.) Harms, *Aglaia periviridis* Hiern, *Aglaia lawii* (Wight) Saldanha, *Margaritaria indica* (Dalz.) Airy Shaw, *Terminalia travancorensis* Wight & Arn. and *Syzygium gardneri* Thw., with a height of 21-30 m. The third storey occupied by the species of *Turpinia malabarica* Gamble, *Aglaia lawii* (Wight) Saldanha, *Knema attenuata* (Hook. f. & Thoms.) Warb., *Diospyros paniculata* Dalz., *Macaranga peltata* (Roxb.) Muell.-Arg., *Myristica beddomei* King, *Canarium strictum* Roxb., *Hydnocarpus macrocarpa* (Bedd.) Warb., *Drypetes malabarica* (Bedd.), *Aglaia periviridis* Hiern, *Paracroton pendulus* ssp. *zeylanicus* (Hassk.) Miq., *Otonephilum stipulaceum* (Bedd.) Radlk., *Vateria indica* L., *Trewia nudiflora* L., *Vernonia arborea* Buch.-Ham., *Dimocarpus longan* Lour., *Toona ciliata* Roem., *Dysoxylum malabaricum* Bedd. ex Hiern, *Cyathocalyx zeylanicus* Champ. ex Hook. f. & Thoms., *Poeciloneuron indicum* Bedd., *Hydnocapus pentandra* (Buch.-Ham.) Oken, *Walsura trifolia* (A. Juss.) Harms, *Polyalthhia fragrans* (Dalz.) Bedd., *Macarnga indica* Wight, *Canarium strictum* Roxb., with 10-20 m. The third layer consists of species such as *Arenga wightii* Griff., *Vernonia*

arborea Buch.-Ham., *Leea indica* (Burm. f.) Merr., *Antiaris toxicaria* Lesch., *Artocarpus hirsutus* Lam., *Xanthophyllum arnottianum* Wight, *Memecylon umbellatum* Burm.f., *Caryota urens* L., *Baccaurea courtallensis* (Wight) Muell.-Arg., *Strombosia ceylanica* Gard., *Wrightia arborea* (Dennst.) Mabb., *Mangifera indica* L., *Callicarpa tomentosa* (L.) L., *Syzygium laetum* (Buch.-Ham.) Gandhi, *Cipadessa baccifera* (Roth) Miq., *Mallotus philippensis* (Lam.) Muell.-Arg. The herbs, shrubs, and climbers include *Stachyphrynium spicatum* (Roxb.) Schum., *Elatostema lineolatum* Wight, *Bolbitis* sp., *Pteris* sp., *Oberonia mucronata* (D. Don) Ormerod & Seidenf., *Sonerila rheedei* Wight & Arn., *Asplenium nidus*, *Hydrocotyle javanica* Thunb., *Remusatia vivipara* (Roxb.) Schott, *Peperomia blanda* (Jacq.) Kunth, *Psychotria anamalayana* Bedd., *Sarcandra chloranthoides* Gard., *Lepisanthes erecta* (Thw.) Leenh., *Leea indica* (Burm. f.) Merr., *Thottea siliquosa* (Lam.) Ding Hou, *Schumannianthus virgatus* (Roxb.) Rolfe, *Lepianthus umbellata* (L.) Rafin., *Ventilago bombaiensis*, *Erythropalum scandens* Blume, *Ancistrocladus heyneanus* Wall. ex Graham, *Sarcostigma kleinii* Wight & Arn. and *Coscinium fenestratum* (Gaertn.) Colebr. are seen.

The spatial view of the population site exhibited the arrangement of individuals of *Drypetes malabarica* in a scattered manner along with their associates along the sides of watercourse. The ground is characterized by slopes, rock boulders, fallen woods, stream etc. The age profile have shown 6 individuals of candidate species consisted of two numbers as set of present (reproductive phase), three numbers of set of future (pre-reproductive phase) and one number of set of past (post reproductive phase) covering a height range from 4-24 m. The

vertical crown projections shows the placement of individuals such as *Cullenia exarillata, Turpinia malabarica*, *Hydnocarpus macrocarpa* and *Vateria indica* etc. just below the tallest individual (Canopy) of *Dysoxylum malabaricum*. The horizontal crown projections had displayed the overlapping canopy coverages under the canopy of tallest individual, *D.malabaricum.*

The population structure of *Drypetes malabarica* was analyzed by recording GBH, basal area, basal cover, age phases, and height of the each individual (Table 1). The floristic diversity analysis covered 57 species of GBH ≥30 cm size of 245 individuals in 5445 sq.m. The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Hydnocarpus macrocarpa* has highest index value of 0.4035 and thus became the dominant species in the particular quadrat whereas, the *Drypetes malabarica* represented 13th position with IVI of 0.0691 (Table 2). In addition, it is noted that female trees are very less in numbers than male trees in the study area.

The area of occurrence of the species in the particular forest area was found to be approximately 3 km^2 and the area of occupancy (area sampled plus non-sampled area) was 0.0036 km^2 and nearly 50 mature trees were seen in the forest patch.

ii. Malakkapara

The vegetation profile (Vertical) of the population located at Malakkapara showed the occurrence of major tree species apart from *Drypetes malabarica* (Bedd.) Airy Shaw, such as *Palaquium*

ellipticum (Dalz.) Baill., *Cullenia exarillata* Robyns,, *Elaeocarpus tuberculatus* Roxb., *Myristica beddomei* King, *Actinodaphne tadulingamii* Gamble, *Mesua ferrea* var. *ferrea* L., *Semecarpus travancoricum* Bedd., *Ficus nervosa* Heyne ex Roth, *Persea macrantha* (Nees) Kosterm., *Poeciloneuron indicum* Bedd, as first layer/storey, reaching a height range of 31-40 m. The second storey consists of *Myristica beddomei* King, *Cullenia exarillata* Robyns, *Aglaia periviridis* Hiern, *Artocarpus heterophyllus* Lam., *Palaquium ellipticum* (Dalz.) Baill., *Ficus nervosa* Heyne ex Roth, *Antiaris toxicaria* Lesch., *Mesua ferrea var. ferrea* L., *Hopea parvifolia* Bedd., with a height of 21-30 m. The third storey is occupied by *Polyalthia fragrans* (Dalz.) Bedd., *Actinodaphne malabarica* Balakr., *Otonephilum stipulaceum* (Bedd.) Radlk., *Turpinia malabarica* Gamble, *Aglaia lawii* (Wight) Saldanha, *Melicope lunu-ankenda* (Gaertn.) Hartley, *Semecarpus travancorica* Bedd., *Ochlandra travancorica* (Bedd.) Benth. ex Gamble, *Aglaia periviridis* Hiern, *Holigarna arnottiana* Hook. f., *Croton malabaricus* Bedd., *Canarium strictum* Roxb., *Aglaia tomentosa* Teijsm. & Binn., *Drypetes venusta* (Wight) Pax & Hoffm., *Holigarnia grahamii* (Wight) Kurz, *Epiprinus mallotiformis* (Muell.-Arg.) Croizat,, *Agrostistachys borneensis* Becc., *Knema attenuata* (Hook.f. & Thoms.) Warb., *Macaranga indica, Antidesma montanum* Blume, *Dimocarpus longan* Lour., *Memecylon umbellatum* Burm.f., *Apollonias arnottii* Nees, *Mastixia arborea* (Wight) Bedd., *Anacolosa densiflora* Bedd. with 10-20m height.

The spatial view of the population site exhibited the arrangement of individuals of *Drypetes malabarica* in a scattered manner along with their associates adjacent to the water course.

The ground is characterized by slopes, rock boulders, fallen woods, stream etc. The age profile have shown 11 individuals of candidate species consisted of four numbers as set of present (reproductive phase), four numbers of set of future (pre-reproductive phase) and three number of set of past (post reproductive phase) covering a height range from 10-26 m. The vertical crown projections shows the placement of individuals such as *Turpinia malabarica* Gamble, *Polyalthia fragrans, Aglaia lawii, Semecarpus travancorica, Drypetes malabarica, Ochlandra travancorica* etc. just below the tallest individual (Canopy), *Cullenia exarillata*. The horizontal crown projections displayed the overlapping canopy coverage's under the canopy of tallest individual, *Cullenia exarillata*.

The population structure of *Drypetes malabarica* was analyzed by recording GBH, basal area, basal cover, age phases and height of the each individual (Table 3). The floristic diversity analysis covered 69 species of GBH ≥30 cm size of 419 individuals in 5445 sq.m. The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Ficus nervosa* had highest index value of 0.285359 and thus became the dominant species in the particular quadrat. Whereas, *Drypetes malabarica* represented 11th position with IVI of 0.077139 (Table 4). In addition, it is noted that female trees are very less in number than male trees in the study area.

The area of occurrence of the species in the forest area was found to be approximately 30 km^2 and the area of occupancy

(area sampled plus non-sampled area) 0.011 km^2 and nearly 150 mature trees were seen in the site.

iii. Shenduruny WLS

The vegetation profile (Vertical) of the population located at Shenduruny WLS had shown the occurrence of major tree species apart from *Drypetes malabarica* (Bedd.) Airy Shaw, such as *Lophopetalum wightianum* Arn., *Hopea racophloea, Anacolosa densiflora* Bedd., *Vateria indica* L., *Dipterocarpus indicus* L., *Syzigium lanceolatum* (Lam.) Wight & Arn., *Kingiodendron pinnatum* (Roxb. ex DC.) *Bischofia javanica* Blume, *Ficus microcarpa* L., *Tetrameles nudiflora* R. Br., *Cullenia exarillata* Robyns, *Calophyllum polyanthum* Wall. ex Choisy, *Gluta travancorica* Bedd., *Terminalia bellirica* (Gaertn.) Roxb. as first layer/storey, reaching the height range 31-40 m. The second storey is represented along with *Drypetes malabarica, Pterospermum diversifolium* Blume, *Flacourtia montana* Graham, *Hydnocarpus pentandra* (Buch.-Ham.) Oken, *Myristica beddomei* King, *Filicium decipiens* (Wight & Arn.) Thw., *Litsea floribunda* (Blume) Gamble, *Holigarna arnottiana* Hook. f., *Diospyros candolleana* Wight, *Glochidion ellipticum* Wight, *Cynometra travancorica* Bedd. with a height of 21-30 m. The third storey is occupied by *Aglaia periviridis* Hiern, *Ixora brachiata* Roxb. ex DC., *Dimocarpus longan* Lour., *Polyalthia coffeoides* (Thw. ex Hook. f. & Thoms.) Hook. f. & Thoms., *Dimorphocalyx glabellus var. lawianus* (Muell.-Arg.) Chakrab. & Balakr., *Polyalthia fragrans* (Dalz.) Bedd., *Sageraea thwaitesii* Hook.f. and Thomson, *Baccaurea courtallensis* (Wight) Muell.-Arg., *Hopea erosa* (Bedd.) Van Sloot., *Turpinia malabarica* Gamble, *Meiogyne pannosa*

(Dalz.) Sinclair, *Cryptocarya wightiana* Thw., *Garcinia spicata* (Wight & Arn.) Hook. f., *Vitex altissima* L. f., *Macranga indica* Wight, *Xanthophyllum arnottianum* Wight with 10-20 m, and below which herbs, shrubs and climbers such as *Arisaema leschenaultia* Blume, *Ophiorrhiza rugosa* Wall. var. *prostrata, Rungia pectinata* (L.). The shrubs include *Psychotria nudiflora* Wight & Arn., *Calamus shendurunii* Anto, Renuka & Sreek., *Calamus lakshmanae* Renuka, and climbers include *Ancistrocladus heyneanus* Wall. ex Graham, *Premna* sp., *Pothos scandens* L., *Pothos armatus* C.E.C. Fisch. etc.

The spatial view of the population site exhibited the arrangement of individuals of *Drypetes malabarica* in a scattered manner along with their associates adjacent to the watercourse. The ground is characterized by slopes, rock boulders, fallen woods, stream etc. The age profile has shown 4 individuals of candidate species consisted of three numbers as set of present (reproductive phase), one number of set of future (pre-reproductive phase) and no set of past (post reproductive phase) covering height range from 10-26 m. The vertical crown projections had shown the placement of individuals such as *Cullenia exarillata, Ardisia* sp., *Xanthophyllum arnottianum, Meiogyne ramarowii, Drypetes malabarica* etc. just below the tallest individual (Canopy) *Gluta travancorica*. The horizontal crown projections had displayed the overlapping canopy coverage's under the canopy of tallest individual, *G. travancorica.*

The population structure of *Drypetes malabarica* was analyzed by recording GBH, basal area, basal cover, age phases and height of the each individual (Table 5). The floristic diversity

analysis covered 63 species of GBH ≥30 cm size of 254 individuals in 5445 sq.m. The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Terminalia bellirica* had highest index value of 0.19567 and thus became the dominant species. Whereas, *Drypetes malabarica* represent 26th position with IVI of 0.03695 (Table 6). In addition, it is noted that female trees are very less in numbers than male trees in the study area.

The area of occurrence of the species in the forest area was found to be approximately 75 km^2 and the area of occupancy (area sampled plus non-sampled area) was 0.0047 km^2 and nearly 65 mature trees were seen in the Sanctuary.

iv. Kulamavu MPCA

The vegetation profile (Vertical) of the population located at Kulamavu MPCA had shown the occurrence of major tree species apart from *Drypetes malabarica* (Bedd.) Airy Shaw, such as *Calophyllum polyanthum* Wall. ex Choisy, *Semecarpus travancorica* Bedd., *Elaeocarpus tuberculatus* Roxb., *Poeciloneuron indicum* Bedd., *Dimocarpus longan* Lour., *Bischofia javanica* Blume, *Syzygium gardneri* Thw., *Cinnamomum macrocarpum* Hook. f., as first layer/storey, reaching height range of 31-40 m. The second storey is represented by *Knema attenuata* (Hook. f. & Thoms.) Warb., *Diospyros paniculata* Dalz., *Gordonia obtusa* Wall.ex Wight & Arn., *Dimorphocalyx glabellus var.lawianus* (Muell.-Arg.) Chakrab. & Balakr., *Mastixia arborea* (Wight) Bedd., *Turpinia malabarica* Gamble, with height of 21-30

m. The third storey is occupied by *Myristica beddomei* King, *Garcinia morella* (Gaertn.) Desv., *Aglaia tomentosa* Teijsm. & Binn., *Apollonias arnotti* Nees, *Croton malabaricus* Bedd., *Syzigium cumini* (L.) Skeels, *Otenophillium stipulaceum* (Bedd.) Radlk. with 10-20 m, and below which species such as *Phoebe lanceolata* Nees, *Vernonia arborea* Buch.-Ham., *Mesua ferrea* L., *Agalai lawii* (Wight) Saldanha, *Litsea bourdilloni* Gamble, *Aphanamyxis polystachya* (Wall.) Parker, *Cryptocarya wightiana* Thw. and *Glochidion ellipticum* Wight.

The spatial view of the population site exhibited the arrangement of individuals of *Drypetes malabarica* in a scattered manner along with their associates, adjacent to the watercourse. The ground is characterized by slopes, rock boulders, fallen woods, streams etc. The age profile shows 7 individuals of candidate species consist of three numbers as set of present (reproductive phase), three numbers of set of future (pre-reproductive phase) and one number of set of past (post reproductive phase) covering height range from 4-20 m. The vertical crown projections had shown the placement of species such as, *Vernonia arborea, Vateria indica, Hydnocarpus macrocarpa* etc. just below the tallest individual (Canopy) of *Mesua ferrea*. The horizontal crown projections had displayed the overlapping canopy coverage's under the canopy of tallest individual, *Mesua ferrea.*

The population structure of *Drypetes malabarica* was analyzed by recording GBH, basal area, basal cover, age phases, sex ratios and height of the each individual (Table7). The floristic

diversity analysis covered 54 species of GBH ≥30 cm size of 223 individuals in 5445 sq.m.

The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Calophyllum polyanthum* has highest index value of 0.3151 and thus became the dominant species. Whereas, *Drypetes malabarica* represented 11th position with IVI of 0.075015 (Table 8). In addition, it is noted that female trees are very less in numbers than male trees in the study area.

The area of occurrence of the species in the MPCA was found to be approximately 1.7 km^2 and the area of occupancy (area sampled plus non-sampled area) was 0.015 km^2 and nearly 200 mature trees were seen in the MPCA.

Plate 1: *Drypetes malabarica* (Bedd.) Airy Shaw- Population Structure

Habit: Different views from Malakkapara forest

Cauliflory Habitat and branching pattern:Views from Neriamangalam forest

View of habit and habitats from Shenduruney WLS

Habit- Different views from Kulamavu MPCA Quadrat marking Soil sample collection

5.1.2. Population Dynamics

5.1.2.1. Vegetative phenology

Flushing of new leaves along with matured leaves were noted in November and the process continued up to March. On attaining half matured stage of the new leaves, the trees began to flower. The young foliage is pale yellowish in colour, are seen in branch tips which later turned to light green and finally to dark green. The leaves are alternate, light green on lower surface. New flushing were often infested and fed by caterpillars (Catterpillar couldn't rear up for adult). Bark is pale yellowish brown in colour with shining smooth surface.

5.1.2.2. Reproductive phenology

The tree is dioecious in nature. Therefore, male and female flowers are seen in separate trees. Flowers are cauliflorous. Male flower bud initiation noted from 1st week of March along with flushing. Flower buds took around 10-12 days for development and blooming. Blooming noted during night hours. The number of flower buds in a single fascicle ranged from 3-32 and blooming was in acropetal manner. The period of blooming extended from 20 to 25 days. The male flowering process in different populations could be seen up to the end of April with slight degree of variations in the intensity of flowering. The flower bud started its blooming between 7- 8pm and completes the process between 12pm -1am. Mature flower buds are globular and brownish in colour. Flowers are creamy white with an unpleasant odour during peak flowering. Four petals are spread

in the base and anthers arranged in an erect position of the centrally located thalamus which is oily and wet on surface. The anthers remain fresh for 12-18 hours and yellow in colour with white filaments, thereafter turns to brown colour and withers. Around 30-40 stamens are present in a single flower. Small honey bees (*Apis cumin*) were seen in large numbers during peak of blooming and other insects or flies were seldom observed.

Female flower bud initiation was noted from 1st week of March along with flushing. Fascicles of different sizes were noted and each fascicle ranged from 2-13 flower buds. Flower buds are yellowish in colour and slightly bigger than the male flower. Similarly flower stalks are also longer than the male. During flowering, few flowers are found withered and fall off. This may be due to false pollination as in the case of Jack tree. The presence of one undeveloped ovule on majority of mature fruits is confirming the ineffective pollination mechanism in the species. Blooming started around 10pm and completes by 1am. During receptive time, stigma was sticky and yellowish white in colour and turned to black when non receptive. Receptivity of stigma lasts 6-8 hours. The female flowering could be seen up to last week of April. During flowering, honey bees were found forage the flowers. Occasional flowering was also noted during the month June. Fruit initiation noted from middle of April.

5.1.2.3. Pollen-Ovule (P:O) ratio

As per Haemocytometer reading, one anther contained 508 pollen grains. It was noted that 48 anthers were presented per flower. Therefore a single flower will have around 24,384 pollen

grains. A female flower had 4 ovules and hence the P: O ratio is 6096:1.

5.1.2.4. Pollen fertility

The acetocarmine staining technique showed that 98% fertile pollens are fertile.

5.1.2.5. Fruit development

Fruit initiation was noted during April middle and extended up to October- November. It will take 6-7 months for fruit maturity. The young fruits are pale brown and on maturity turns to moderately dark brown in colour. The fruit is basically a drupe, A mature fruit have 27-32x 23-27mm, ovoid to ellipsoid, weighs 10-13 gm containing 1or 2 seeds. Each seed weighs1-2 gram and calculated into 400-500 seeds holds 1kg. Fruits are found often attacked by insect-pest. Fruits of 2-3 months old were found punctured on surface by the insect pest. On dissection, it is found that the endosperm was eaten by caterpillars. About 40% fruits get destroyed by the incidence of insect pest. We could not collect or rear the pest for adult identity. Fruits of 5- 6 months old were found largely predated by Malabar Grey Horn Bill (*Tockus griseus*), Flying squirrel (*Petaurista philippensis*), Giant squirrel (*Ratufa indica*) etc. The fallen fruits were also found attacked by caterpillars and which led to the total degradation of seeds and arrest natural regeneration.

5.1.3. Causal factors for population reduction

- The low area of occurrance and preproductive individuals in the respective communities indicate its fewness among associates.
- Fruit infestation by insect pest was noted to be around 30-40%.
- Ripened fruit and seed predation was noted to be 60-70%
- Fallen fruits/seeds were predated to be 10-20% by Spiny dormouse *(Platacanthomys lasiurus*) as ground predator.
- Pollination/ Fertilization problems leading to underdeveloped seed in the ovary cells.

5.1.4. Climatic and Edaphic Factors

Climatological and Edaphological data of the species were collected in three seasons of the year and were recorded and tabulated. Average value of climatic data such as atmospheric day temperature, atmospheric humidity as well as night temperature, night humidity of each season is presented in Table 9, 11, 13 &15. Similarly soil samples from three levels (such as surface, 15cm deep as middle and 30cm deep as bottom) were collected and data on texture, pH, nutrients, etc. were also recorded. Soil moisture content, soil temperature of each seasons were also collected and presented in Table 10, 12, 14, & 16.

Plate 2: *Drypetes malabarica* (Bedd.) Airy Shaw- Population Dynamics

Leaf flushing - A view

Male inflorescence

Female inflorescence

Fruiting branch

Matured fruits

Infested fruits

L.S. of fruits showing seed infestation and undeveloped ovules

Disintegration of fallen fruits
Inset: Caterpillar infested fruit

5.1.5. Conservation Strategies

5.1.5.1. Vegetative propagation

Propagation through stem cuttings and air layering were tried for vegetative multiplication of the species. Stem cuttings along with auxins such as IAA, IBA and NAA of different concentrations were attempted for root initiation. Aged branch cuttings were found difficult for rooting however, juvenile stem cuttings taken from 2-3 years old saplings have shown callus initiation and subsequent rooting. Rooting was recorded 32-93 days after planting the cuttings and 100% success achieved with NAA 3000ppm whereas only 13% success for control (Table 17). In the case of air layering, young stands of 2 years old, responded positively and rooted within 22-131 days. Layering with 1000ppm IAA gave 100% success whereas only 50% success noted in the control (Table 18). The plant has also exhibited reiterating ability which ensures the growth of the parent plants even after separation of air layered rooted portion from the main stock.

5.1.5.2. Seed propagation

The ripened fruits were collected and removed the fleshy fruit rind. The processed seeds were analyzed for initial moisture content and associated germination studies. The fresh seeds with initial moisture content of 46% were found with 50% germination in 28-32 days using river sand as the sowing medium in nursery conditions. The seeds lost viability within two weeks when kept in open plastic trays in ambient conditions (control). Critical MC was noted as 28-30% with 20%

germination (Table 19). The germination type is hypogeal and seedlings exhibited heterophylly in their early stages of growth. The seeds were found tolerant to desiccation and at the same time sensitive towards chilling condition. Therefore, the seeds were categorized as intermediate type. In order to break the dormancy of seeds, both physical and chemical pre-treatments were tried. This includes soaking of seeds in cold water over night, hot water (80ºC) for 5 minutes and acid (H_2SO_4) scarification for 5 minutes. The seed germination of 50% was resulted in the acid treatment within 20-31 days compared to 28-32 days in control. (Table 20). The extream predation of ripened fruits caused limited seed avaibility and therefore discontinued the seed storage trials further.

Plate 3: *Drypetes malabarica* (Bedd.) Airy Shaw- Conservation

Rooting of stem cuttings with the aid of auxins

A view of air Layering in natural stands

Views of air Layering success

Processed seeds Seed Germination Seedling stock in the nursery

5.1.6. Restoration

Four natural evergreen ecosystems in the Western Ghats of Kerala region were selected for *in-situ* recovery planting. In addition to these, three more sites were selected for *ex situ* planting. (Table 21 and 22).

A total of 400 seedlings were reintroduced in four natural habitats (*in situ*). Fully established 2-yr old polybagged seedlings having an average height of 22-33cm were transported from the nursery to the planting sites. Pits were prepared in tune with canopy gaps in the population areas. Each seedling was tag-marked for monitoring. Planting of the seedlings was done during June-July. Further, 35 seedlings were casualty planted in three sites. The establishment and survival performance of the seedlings were carried out on half yearly basis. 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. Neriamangalam

One hundred seedlings of 1.0 - 1.5 years old were planted at Kulamankuzhikudi, near Neriamangalam. The mean height of seedlings during planting was 26cm and the maximum height was 41 cm. The seedlings showed 80% survival alongwith average height of 33cm and maximum height of 50cm after 1.5 years of planting. The seedling survival in the site was found affected by poor monsoon.

2. Kulamavu MPCA

One hundred seedlings of 1.0 - 1.5 years old were planted in the site. The mean height of seedlings during planting was 29cm and the maximum height was 44 cm. The seedlings showed 82% survival along with average height of 33cm and a maximum height of 51cm after 1.5 years of planting. Shortage of SW monsoon, elephant trampling etc. contributed to the mortality of seedlings in the site.

3. Rosemala

One hundred seedlings of 1.0 - 1.5 years old were planted in the site. The mean height of seedlings during planting was 22cm and the maximum height recorded was 37 cm. The seedlings showed 74% survival along with average height of 29cm and a maximum height of 51cm after 1.5 years of field planting. In addition to the poor SW monsoon, the survival of plants was found affected by wildlife interventions particularly browsing by deer.

4. Malakkapara

One hundred seedlings of 1.0 - 1.5 years old were planted at Pathadipalam, near Malakkapara. The mean height of seedlings during planting was 24cm and the maximum height was 45 cm. The seedlings showed 74% survival along with average height of 28cm and a maximum height of 52cm after 1.5 years of planting. The shortage of rain, wildlife interventions along with caterpillar leaf infestation affected the survival of seedlings in the site.

Plate 4: *Drypetes malabarica* (Bedd.) Airy Shaw- Restoration *in situ*

Views of seedling transportation, planting and display board: Neriamangalam

Views at Malakkapara

Views at Rosemala

Views at Kulamavu MPCA

A total of 150 seedlings of the species were also planted in three *ex situ* viz.,

1. FRC Velupadam

Fifty seedlings of *Drypetes malabarica* were planted at FRC (Field Research Centre) Velupadam. The mean seedling height during planting was 32cm and the maximum height was 51cm. The seedlings showed 98% survival after 3 months. Few seedlings were found affected by deer browsing.

2. Sub-centre Nilambur

Fifty seedlings were planted at KFRI Sub-centre, Nilambur. The mean seedling height during planting was 33cm and the maximum height was 52cm. The seedlings showed 96% survival after 3 months. Few seedlings were found affected by wild boar browsing.

3. KFRI Arboretum, Peechi

Fifty seedlings were planted at KFRI Arboretum, Peechi. The mean seedling height during planting was 27cm and the maximum height was 44cm. The seedlings showed 76% survival after 4 months. Few seedlings were found affected by cattle browsing.

Plate 5: ***Drypetes malabarica*** (Bedd.) Airy Shaw- **Planting** ***ex situ***

Different views of seeding planting, protection work and evaluation: FRC Velupadam

Different views of seeding planting, protection work and evaluation: Sub centre Nilambur

Different views of seeding growing: KFRI Arboretum

Table: 1
Population Structure of *Drypetes malabarica*: Neriamangalam
(List of individuals with G≥30 cm represented**)**

Sl. No.	GBH (cm)	r (cm)	Basal area (cm^2)	Basal Cover (m)	Age Phase	First branching seen at (m)	Height of Stand (m)
1.	121	19.27	1165.99	14	Set of present	5.0	24
2.	142	22.61	1605.21	13	Set of past	6.0	20
3.	70	11.15	390.37	8	Set of future	5.0	12
4.	30	4.78	71.74	4	Set of future	3.0	4
5.	85	13.54	575.66	8	Set of present	1.5	12
6.	35	05.57	97.42	4	Set of future	2.0	4

Table: 2
Floristic diversity/Importance Value Index of *Drypetes malabarica*: Neriamangalam
(List of individuals with G≥ 30 cm represented)

Sl. No.	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Hydnocarpus macrocarpa*	Flacourtiaceae	0.0425	0.2163	0.1561	0.4150
2	*Dysoxylum malabaricum*	Meliaceae	0.0425	0.0326	0.1147	0.1899
3	*Knema attenuata*	Myristicaceae	0.0531	0.0653	0.0516	0.1701
4	*Poeciloneuron indicum*	Clusiaceae	0.0319	0.0122	0.0935	0.1377
5	*Aglaia lawii*	Meliaceae	0.0319	0.0489	0.0393	0.1201
6	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.0106	0.0081	0.0906	0.1094
7	*Aglaia periviridis*	Meliaceae	0.0319	0.0367	0.0346	0.1033
8	*Polyalthia fragrans*	Annonaceae	0.0212	0.0653	0.0090	0.0956
9	*Vateria indica*	Dipterocarpaceae	0.0319	0.0244	0.0349	0.0913
10	*Bischofia javanica*	Euphorbiaceae	0.0106	0.0081	0.0625	0.0813
11	*Myristica beddomei*	Myristiaceae	0.0319	0.0285	0.0100	0.0705
12	*Otonephelium stipulaceum*	Sapindaceae	0.0212	0.0204	0.0275	0.0691
13	*Drypetes malabarica*	Euphorbiaceae	0.0319	0.0244	0.0127	0.0691
14	*Mesua thwaitesii*	Clusiaceae	0.0212	0.0122	0.0336	0.0672
15	*Turpinia malabarica*	Staphyleaceae	0.0212	0.0204	0.0237	0.0654
16	*Diospyros paniculata*	Ebenaceae	0.0319	0.0163	0.0136	0.0618
17	*Vernonia arborea*	Asteraceae	0.0212	0.0285	0.0079	0.0577
18	*Paracroton pendulus ssp. zeylanicus*	Euphorbiaceae	0.0212	0.0204	0.0127	0.0544

19	*Macaranga peltata*	Euphorbiaceae	0.0212	0.0163	0.0159	0.0535
20	*Hydnocarpus pentandra*	Flacourtiaceae	0.0212	0.0163	0.0090	0.0466
21	*Canarium strictum*	Burseraceae	0.0319	0.0122	0.0015	0.0456
22	*Palaquium ellipticum*	Sapotaceae	0.0106	0.0244	0.0077	0.0428
23	*Baccaurea courtallensis*	Euphorbiaceae	0.0212	0.0204	0.0009	0.0426
24	*Mallotus tetracoccus*	Euphorbiaceae	0.0106	0.0081	0.0232	0.0421
25	*Walsura trifolia*	Meliaceae	0.0106	0.0163	0.0120	0.0390
26	*Cyathocalyx zeylanica*	Annonaceae	0.0106	0.0204	0.0056	0.0367
27	*Otonephilium stipulaceum*	Sapindaceae	0.0106	0.0081	0.0169	0.0357
28	*Antiaris toxicaria*	Moraceae	0.0212	0.0122	0.0015	0.0350
29	*Palaquium ellipticum*	Sapotaceae	0.0106	0.0040	0.0179	0.0327
30	*Dimocarpus longan*	Sapindaceae	0.0212	0.0081	0.0013	0.0308
31	*Terminalia travancorensis*	Combretaceae	0.0106	0.0081	0.0110	0.0298
32	*Holigarna grahamii*	Anacardiaceae	0.0106	0.0081	0.0096	0.0284
33	*Memecylon umbellatum*	Melastomataceae	0.0106	0.0122	0.0026	0.0255
34	*Arenga wightii*	Areacaceae	0.0106	0.0122	0.0023	0.0252
35	*Margaritaria indica*	Euphorbiaceae	0.0106	0.0040	0.0081	0.0228
36	*Toona ciliata*	Meliaceae	0.0106	0.0081	0.0009	0.0197
37	*Cipadessa baccifera*	Meliaceae	0.0106	0.0081	0.0007	0.0195
38	*Mastixia arborea*	Cornaceae	0.0106	0.0040	0.0034	0.0182
39	*Syzygium gardneri*	Mytaceae	0.0106	0.0040	0.0034	0.0182
40	*Trewia nudiflora*	Euphorbiaceae	0.0106	0.0040	0.0031	0.0178
41	*Syzygium laetum*	Myrtaceae	0.0106	0.0040	0.0022	0.0169
42	*Antidesma montanum*	Euphorbiaceae	0.0106	0.0040	0.0020	0.0167
43	*Leea indica*	Leeaceae	0.0106	0.0040	0.0010	0.0158
44	*Actinodaphne malabarica*	Lauraceae	0.0106	0.0040	0.0009	0.0156
45	*Xanthophyllum arnottianum*	Polygalaceae	0.0106	0.0040	0.0009	0.0156
46	*Glochidion ellipticum*	Euphorbiaceae	0.0106	0.0040	0.0007	0.0154
47	*Memecylon umbellatum*	Melastomataceae	0.0106	0.0040	0.0005	0.0152
48	*Xanthophyllum arnottianum*	Polygalaceae	0.0106	0.0040	0.0004	0.0151
49	*Mallotus philippensis*	Euphorbiaceae	0.0106	0.0040	0.0003	0.0150
50	*Aporosa cardiosperma*	Euphorbiaceae	0.0106	0.0040	0.0003	0.0150
51	*Holigarna arnottiana*	Anacardiaceae	0.0106	0.0040	0.0003	0.0150
52	*Caryota urens*	Arecaceae	0.0106	0.0040	0.0003	0.0150
53	*Artocarpus hirsutus*	Moraceae	0.0106	0.0040	0.0002	0.0149
54	*Mangifera indica*	Anacardiaceae	0.0106	0.0040	0.0001	0.0148
55	*Strombosia zeylanica*	Olacaceae	0.0106	0.0040	0.0001	0.0148
56	*Callicarpa tomentosa*	Verbenaceae	0.0106	0.0040	0.0001	0.0148
57	*Wrightia arborea*	Apocynaceae	0.0106	0.0040	0.0001	0.0148

Table: 3
Population Structure of *Drypetes malabarica*: Malakkapara
(List of individuals with G≥30 cm represented**)**

Sl. No.	GBH (cm)	r (cm)	Basal area (cm^2)	Basal Cover (m)	Age Phase	First branching seen at (m)	Height of Stand (m)
1	127	20.22	1283.78	2.0	set of past	5.5	18
2	151	24.05	1816.18	4.0	set of past	10.0	30
3	35	5.57	97.42	1.0	set of future	3.0	8
4	67	10.67	357.49	2.0	set of future	5.0	16
5	56	8.92	249.84	1.5	set of future	4.0	12
6	107	17.04	911.74	5.0	set of present	8.0	22
7	143	22.78	1629.44	3.0	set of past	7.5	22
8	82	13.06	535.57	2.5	set of present	6.0	13
9	116	18.47	1071.18	3.0	set of present	7.0	22
10	77	12.26	471.97	2.5	set of future	6.5	20
11	105	16.72	877.81	3.5	set of present	5.0	25

Table: 4
Floristic diversity/Importance Value Index of
***Drypetes malabarica*: Malakkapara**
(List of individuals with G≥ 30 cm represented)

Sl. No	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Ficus nervosa*	Moraceae	0.0073	0.0047	0.2732	0.2853
2	*Vateria indica*	Dipterocarpaceae	0.0367	0.0787	0.0717	0.1872
3	*Cullenia exarillata*	Bombacaceae	0.0294	0.0572	0.0772	0.1639
4	*Palaquium ellipticum*	Sapotaceae	0.0367	0.0405	0.0746	0.1519
5	*Mesua ferrea var. ferrea*	Clusiaceae	0.0220	0.0143	0.0833	0.1197
6	*Dendrocnide sinuata*	Urticaceae	0.0220	0.0906	0.0047	0.1175
7	*Turpinia malabarica*	Staphylaceae	0.0220	0.0501	0.0401	0.1123
8	*Oreocnide integrifolia*	Urticaceae	0.0220	0.0787	0.0084	0.1092
9	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.0147	0.0214	0.0648	0.1010

10	*Knema attenuata*	Myristicaceae	0.0220	0.0119	0.0437	0.0777
11	*Drypetes malabarica*	Euphorbiaceae	0.0294	0.0262	0.0214	0.0771
12	*Otonephelium stipulaceum*	Sapindaceae	0.0367	0.0334	0.0056	0.0758
13	*Antidesma montanum*	Euphorbiaceae	0.0294	0.0286	0.0149	0.0730
14	*Litsea floribunda*	Lauraceae	0.0294	0.0286	0.0058	0.0639
15	*Agrostistachys borneensis*	Euphorbiaceae	0.0220	0.0358	0.0045	0.0624
16	*Dimocarpus longan*	Sapindaceae	0.0147	0.0286	0.0116	0.0550
17	*Aglaia tomentosa*	Meliaceae	0.0294	0.0190	0.0035	0.0520
18	*Melicope lunu-ankenda*	Rutaceae	0.0147	0.0167	0.0195	0.0509
19	*Drypetes venusta*	Euphorbiaceae	0.0294	0.0167	0.0041	0.0503
20	*Myristica beddomei*	Myristicaceae	0.0220	0.0143	0.0136	0.0500
21	*Glochidion zeylanicum*	Euphorbiaceae	0.0220	0.0190	0.0055	0.0466
22	*Macaranga indica*	Euphorbiaceae	0.0294	0.0119	0.0044	0.0457
23	*Holigarna grahamii*	Anacardiaceae	0.0147	0.0095	0.0176	0.0419
24	*Persea macrantha*	Lauraceae	0.0147	0.0047	0.0201	0.0396
25	*Semecarpus travancorica*	Anacardiaceae	0.0147	0.0047	0.0197	0.0392
26	*Aporosa acuminata*	Euphorbiaceae	0.0147	0.0214	0.0005	0.0367
27	*Epiprinus mallotiformis*	Euphorbiaceae	0.0220	0.0119	0.0024	0.0364
28	*Artocarpus heterophyllus*	Moraceae	0.0073	0.0047	0.0210	0.0331
29	*Poeciloneuron indicum*	Clusiaceae	0.0073	0.0143	0.0099	0.0316
30	*Aglaia perviridis*	Meliaceae	0.0147	0.0095	0.0065	0.0308
31	*Mesua thwaitesii*	Clusiaceae	0.0073	0.0167	0.0014	0.0254
32	*Apollonias arnottii*	Lauraceae	0.0147	0.0095	0.0006	0.0249
33	*Eugenia sp.*	Myrtaceae	0.0147	0.0095	0.0005	0.0247
34	*Diospyros sp.*	Ebenaceae	0.0147	0.0047	0.0045	0.0240
35	*Aglaia lawii*	Meliaceae	0.0147	0.0071	0.0005	0.0224
36	*Meiogyne ramarowii*	Annonaceae	0.0147	0.0071	0.0004	0.0222
37	*Croton malabaricus*	Euphorbiaceae	0.0147	0.0047	0.0021	0.0216
38	*Mastixia arborea*	Cornaceae	0.0147	0.0047	0.0015	0.0210
39	*Canarium strictum*	Burseraceae	0.0147	0.0047	0.0001	0.0196
40	*Xanthophyllum arnottianum*	Polygalaceae	0.0073	0.0095	0.0009	0.0178
41	*Phoebe lanceolata*	Lauraceae	0.0073	0.0095	0.0006	0.0175
42	*Lagerstroemia microcarpa*	Lythraceae	0.0073	0.0023	0.0069	0.0166
43	*Meliosma simplicifolia*	Fabiaceae	0.0073	0.0071	0.0010	0.0155
44	*Hopea parvifolia*	Dipterocarpaceae	0.0073	0.0023	0.0055	0.0153
45	*Baccaurea courtallensis*	Euphorbiaceae	0.0073	0.0071	0.0005	0.0150
46	*Boehmeria glomerulifera*	Urticaceae	0.0073	0.0071	0.0001	0.0146

47	*Psychotria anamalayana*	Rubiaceae	0.0073	0.0071	0.0001	0.0145
48	*Memecylon umbellatum*	Melastomataceae	0.0073	0.0047	0.0013	0.0134
49	*Vernonia arborea*	Asteraceae	0.0073	0.0047	0.0010	0.0132
50	*Paracroton pendulus ssp. zeylanicus*	Euphorbiaceae	0.0073	0.0047	0.0008	0.0129
51	*Holigarna arnottiana*	Anacardiaceae	0.0073	0.0047	0.0007	0.0128
52	*Gomphandra tetrandra*	Icacinaceae	0.0073	0.0047	0.0005	0.0126
53	*Anacolosa densiflora*	Olacaceae	0.0073	0.0023	0.0027	0.0124
54	*Syzygium laetum*	Myrtaceae	0.0073	0.0047	0.0002	0.0123
55	*Thottea siliquosa*	Aristolochiaceae	0.0073	0.0047	0.0001	0.0121
56	*Actinodaphne malabarica*	Lauraceae	0.0073	0.0023	0.0023	0.0120
57	*Bischofia javanica*	Euphorbiaceae	0.0073	0.0023	0.0015	0.0113
58	*Antiaris toxicaria*	Moraceae	0.0073	0.0023	0.0014	0.0112
59	*Polyalthia fragrans*	Annonaceae	0.0073	0.0023	0.0012	0.0110
60	*Garcinia morella*	Clusiaceae	0.0073	0.0023	0.0007	0.0104
61	*Aphanamixis polystachya*	Meliaceae	0.0073	0.0023	0.0005	0.0102
62	*Leea indica*	Leeaceae	0.0073	0.0023	0.0002	0.0100
63	*Actinodaphne tadulingamii*	Lauraceae	0.0073	0.0023	0.0002	0.0099
64	*Aglaia malabarica*	Meliaceae	0.0073	0.0023	0.0001	0.0099
65	*Ficus tsjahela*	Moraceae	0.0073	0.0023	0.0001	0.0098
66	*Actephila excelsa*	Euphorbiaceae	0.0073	0.0023	0.0001	0.0098
67	*Clausena indica*	Rutaceae	0.0073	0.0023	0.0001	0.0097
68	*Dipterocarpus indicus*	Diptocarpaceae	0.0073	0.0023	0.0001	0.0097
69	*Lasianthus acuminatus*	Rubiaceae	0.0073	0.0023	0.0001	0.0097

Table: 5
Population Structure of *Drypetes malabarica*: Shenduruny WLS
(List of individuals with G≥30 cm represented**)**

Sl. No.	GBH (cm)	r (cm)	Basal area (cm^2)	Basal Cover (m)	Age Phase	First branching seen at (m)	Height of Stand (m)
1	80	12.74	509.65	9.0	set of present	4.0	16
2	78	12.42	484.37	7.5	set of present	7.0	18
3	75	11.94	447.65	8.0	set of future	6.0	18
4	98	15.61	765.13	8.0	set of present	5.0	20

Table: 6
Floristic diversity/Importance Value Index of *Drypetes malabarica*: Shenduruny WLS
(List of individuals with G≥ 30 cm represented)

Sl. No	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Terminalia bellirica*	Combretaceae	0.0106	0.0098	0.1752	0.1956
2	*Vateria indica*	Dipterocarpaceae	0.0425	0.0833	0.0513	0.1771
3	*Bischofia javanica*	Euphorbiaceae	0.0106	0.0343	0.1279	0.1729
4	*Ixora brachiata*	Rubiaceae	0.0319	0.0784	0.0162	0.1266
5	*Hopea racophloea*	Dipterocarpaceae	0.0425	0.0294	0.0491	0.1211
6	*Dimocarpus longan*	Sapindaceae	0.0319	0.0539	0.0273	0.1131
7	*Knema attenuata*	Myristicaceae	0.0425	0.0490	0.0176	0.1091
8	*Xanthophyllum arnottianum*	Polygalaceae	0.0425	0.0392	0.0098	0.0916
9	*Dipterocarpus indicus*	Dipterocarpaceae	0.0212	0.0098	0.0602	0.0912
10	*Syzygium lanceolatum*	Myrtaceae	0.0212	0.0441	0.0222	0.0876
11	*Anacolosa densiflora*	Olacaeae	0.0319	0.0343	0.0191	0.0853
12	*Ficus microcarpa*	Moraceae	0.0106	0.0147	0.0576	0.0830
13	*Kingiodendron pinnatum*	Caesalpiniaceae	0.0319	0.0294	0.0146	0.0760
14	*Gluta travancorica*	Anacardiaceae	0.0106	0.0245	0.0279	0.0630
15	*Palaquium ellipticum*	Sapotaceae	0.0212	0.0147	0.0266	0.0626
16	*Lophopetalum wightianum*	Celastraceae	0.0106	0.0147	0.0363	0.0617
17	*Calophyllum polyanthum*	Clusiaceae	0.0106	0.0049	0.0426	0.0581
18	*Cynometra travancorica*	Caesalpiniaceae	0.0212	0.0196	0.0163	0.0571
19	*Myristica beddomei*	Myristicaceae	0.0212	0.0196	0.0162	0.0571
20	*Cullenia exarillata*	Bombacaceae	0.0106	0.0049	0.0406	0.0561
21	*Syzygium laetum*	Myrtaceae	0.0212	0.0245	0.0022	0.0479
22	*Aglaia periviridis*	Meliaceae	0.0212	0.0147	0.0101	0.0461
23	*Diospyros candolleana*	Ebenaceae	0.0212	0.0147	0.0079	0.0439
24	*Baccaurea courtallensis*	Euphorbiaceae	0.0212	0.0147	0.0018	0.0378
25	*Strombosia ceylanica*	Olacaceae	0.0212	0.0147	0.0010	0.0370
26	*Drypetes malabarica*	Euphorbiaceae	0.0106	0.0196	0.0066	0.0369
27	*Inga cynometroides*	Mimosaceae	0.0106	0.0245	0.0012	0.0363
28	*Hydnocarpus pentandra*	Flacourtiaceae	0.0106	0.0098	0.0139	0.0343
29	*Harpullia arborea*	Sapindaceae	0.0212	0.0098	0.0019	0.0330
30	*Grewia tiliifolia*	Tiliaceae	0.0106	0.0098	0.0085	0.0290

31	*Litsea coriacea*	Lauraceae	0.0106	0.0147	0.0022	0.0275
32	*Polyalthia coffeoides*	Annonaceae	0.0106	0.0147	0.0013	0.0266
33	*Macaranga indica*	Euphorbiaceae	0.0106	0.0098	0.0055	0.0260
34	*Litsea floribunda*	Lauraceae	0.0106	0.0098	0.0050	0.0254
35	*Holigarna arnottiana*	Anacardiaceae	0.0106	0.0098	0.0041	0.0246
36	*Hopea erosa*	Dipterocarpaceae	0.0106	0.0098	0.0035	0.0239
37	*Toona ciliata*	Meliaceae	0.0106	0.0049	0.0080	0.0235
38	*Tetrameles nudiflora*	Datiscaceae	0.0106	0.0049	0.0069	0.0225
39	*Garcinia spicata*	Clusiaceae	0.0106	0.0098	0.0019	0.0223
40	*Actinodaphne malabarica*	Lauraceae	0.0106	0.0098	0.0017	0.0221
41	*Pterospermum diversifolium*	Stercuilaceae	0.0106	0.0049	0.0063	0.0218
42	*Dysoxylum malabaricum*	Meliaceae	0.0106	0.0098	0.0012	0.0217
43	*Turpinia malabarica*	Staphyleaceae	0.0106	0.0049	0.0061	0.0217
44	*Polyalthia fragrans*	Annonaceae	0.0106	0.0098	0.0010	0.0214
45	*Sageraea thwaitesii*	Annonaceae	0.0106	0.0098	0.0009	0.0213
46	*Dimorphocalyx glabellus var. lawianus*	Euphorbiaceae	0.0106	0.0098	0.0008	0.0212
47	*Pterygota alata*	Sterculiaceae	0.0106	0.0049	0.0049	0.0204
48	*Bombax ceiba*	Bombacaceae	0.0106	0.0049	0.0043	0.0198
49	*Cinnamomum malabatrum*	Lauraceae	0.0106	0.0049	0.0033	0.0189
50	*Filicium decipiens*	Sapindaceae	0.0106	0.0049	0.0031	0.0187
51	*Aglaia barberi*	Meliaceae	0.0106	0.0049	0.0029	0.0184
52	*Vitex altissima*	Vrbenaceae	0.0106	0.0049	0.0028	0.0184
53	*Flacourtia Montana*	Flacourtiaceae	0.0106	0.0049	0.0024	0.0179
54	*Meiogyne pannosa*	Annonaceae	0.0106	0.0049	0.0017	0.0172
55	*Drypetes venusta*	Euphorbiaceae	0.0106	0.0049	0.0013	0.0168
56	*Mangifera indica*	Anacardiaceae	0.0106	0.0049	0.0011	0.0166
57	*Cryptocarya wightiana*	Lauraceae	0.0106	0.0049	0.0007	0.0163
58	*Otonephilium stipulaceum*	Sapindaceae	0.0106	0.0049	0.0006	0.0162
59	*Orophea erythrocarpa*	Annonaceae	0.0106	0.0049	0.0005	0.0160
60	*Tabernaemontana alternifolia*	Apocynaceae	0.0106	0.0049	0.0005	0.0160
61	*Aglaia tomentosa*	Meliaceae	0.0106	0.0049	0.0004	0.0159
62	*Gomphandra coriacea*	Icacinaceae	0.0106	0.0049	0.0002	0.0157
63	*Leea indica*	Leeaceae	0.0106	0.0049	0.0002	0.0157

Table: 7
Population Structure of *Drypetes malabarica*: Kulamavu MPCA
(List of individuals with G≥30 cm represented**)**

Sl. No.	GBH (cm)	r (cm)	Basal area (cm^2)	Basal Cover (m)	Age Phase	First branching seen at (m)	Height of Stand (m)
1	147	23.41	1720.81	14	setof present	7.0	25
2	134	21.34	1429.94	12	set of past	7.5	24
3	56	8.92	249.84	3.0	set of future	2.5	7
4	30	4.78	71.74	2.5	set of future	2.0	4
5	100	15.92	795.82	8.0	setof present	4.0	16
6	51	8.12	207.03	4.5	set of present	4.0	10
7	39	6.21	121.09	3.5	set of future	3.0	8

Table: 8
Floristic diversity/Importance Value Index of *Drypetes malabarica*: Kulamavu MPCA
(List of individuals with G≥ 30 cm represented)

Sl. No.	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Calophyllum polyanthum*	Clusiaceae	0.04	0.0538	0.2213	0.3151
2	*Gordonia obtusa*	Theaceae	0.02	0.0762	0.1231	0.2193
3	*Knema attenuata*	Myristicaceae	0.04	0.0672	0.0772	0.1845
4	*Turpinia malabarica*	Staphyleaceae	0.05	0.0717	0.0592	0.1809
5	*Dimocarpus longan*	Sapindaceae	0.04	0.0358	0.0559	0.1317
6	*Antidesma montanum*	Euphorbiaceae	0.03	0.0807	0.0119	0.1226
7	*Myristica beddomei*	Myristicaceae	0.04	0.0493	0.0310	0.1204
8	*Bischofia javanica*	Euphorbiaceae	0.03	0.0224	0.0661	0.1185
9	*Aporosa acuminate*	Euphorbiaceae	0.04	0.0493	0.0042	0.0935
10	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.01	0.0089	0.0657	0.0846
11	*Drypetes malabarica*	Euphorbiaceae	0.03	0.0313	0.0136	0.0750
12	*Erythroxylum lanceolatum*	Erythroxylaceae	0.03	0.0313	0.0112	0.0726
13	*Diospyros paniculata*	Ebenaceae	0.03	0.0224	0.0174	0.0698
14	*Cinnamomum macrocarpum*	Lauraceae	0.02	0.0224	0.0237	0.0661
15	*Mastixia arborea*	Cornaceae	0.03	0.0179	0.0072	0.0551
16	*Cryptocarya wightiana*	Lauraceae	0.02	0.0134	0.0201	0.0536
17	*Aglaia lawii*	Meliaceae	0.03	0.0179	0.0013	0.0492
18	*Antidesma montanum*	Euphorbiaceae	0.02	0.0224	0.0038	0.0463

19	*Semecarpus travancorica*	Anacardiaceae	0.01	0.0089	0.0269	0.0459
20	*Dimorphocalyx glabellus var. lawianus*	Euphorbiaceae	0.02	0.0179	0.0049	0.0428
21	*Actinodaphne sp.*	Lauraceae	0.02	0.0179	0.0045	0.0424
22	*Mesua thwaitesii*	Clusiaceae	0.01	0.0044	0.0272	0.0417
23	*Syzygium gardneri*	Myrtaceae	0.01	0.0134	0.0162	0.0397
24	*Poeciloneuron indicum*	Clusiaceae	0.01	0.0089	0.0184	0.0374
25	*Aglaia periviridis*	Meliaceae	0.01	0.0179	0.0082	0.0361
26	*Mesua ferrea*	Clusiaceae	0.02	0.0134	0.0017	0.0352
27	*Syzygium laetum*	Myrtaceae	0.02	0.0134	0.0016	0.0350
28	*Xanthophyllum arnottianum*	Polygalaceae	0.02	0.0134	0.0014	0.0348
29	*Litsea bourdillonii*	Lauraceae	0.01	0.0224	0.0016	0.0341
30	*Macaranga indica*	Euphorbiaceae	0.02	0.0089	0.0050	0.0340
31	*Aglaia tomentosa*	Meliaceae	0.02	0.0089	0.0034	0.0323
32	*Garcinia morella*	Clusiaceae	0.02	0.0089	0.0023	0.0313
33	*Glochidion ellipticum*	Euphorbiaceae	0.02	0.0089	0.0021	0.0311
34	*Terminalia travancorensis*	Combretaceae	0.01	0.0089	0.0083	0.0272
35	*Walsura trifolia*	Meliaceae	0.01	0.0044	0.0087	0.0232
36	*Croton malabaricus*	Euphorbiaceae	0.01	0.0089	0.0038	0.0227
37	*Acronychia pedunculata*	Rutaceae	0.01	0.0044	0.0077	0.0222
38	*syzygium cumini*	Myrtaceae	0.01	0.0089	0.0018	0.0207
39	*Mangifera indica*	Anacardiaceae	0.01	0.0044	0.0055	0.0200
40	*Strombosia ceylanica*	Olacaceae	0.01	0.0089	0.0009	0.0199
41	*Actinodaphne tadulingamii*	Lauraceae	0.01	0.0089	0.0006	0.0196
42	*Otonephilium stipulaceum*	Sapindaceae	0.01	0.0044	0.0041	0.0186
43	*Flacourtia Montana*	Flacourtiaceae	0.01	0.0044	0.0040	0.0184
44	*Mitragyna parvifolia*	Rubiaceae	0.01	0.0044	0.0039	0.0184
45	*Apollonias arnotii*	Lauraceae	0.01	0.0044	0.0022	0.0167
46	*Haldina cordifolia*	Rubiaceae	0.01	0.0044	0.0021	0.0166
47	*Myristica malabarica*	Myristicaceae	0.01	0.0044	0.0012	0.0157
48	*Vernonia arborea*	Asteraceae	0.01	0.0044	0.0012	0.0157
49	*Phoebe lanceolata*	Lauraceae	0.01	0.0044	0.0006	0.0150
50	*Harpullia arborea*	Sapindaceae	0.01	0.0044	0.0005	0.0150
51	*Baccaurea courtallensis*	Euphorbiaceae	0.01	0.0044	0.0005	0.0150
52	*Aphanamyxis polystachya*	Meliaceae	0.01	0.0044	0.0003	0.014
53	*Canarium strictum*	Burseraceae	0.01	0.0044	0.0003	0.0147
54	*Dysoxylum malabaricum*	Meliaceae	0.01	0.0044	0.0002	0.0147

Table: 9
Climatological data of *Drypetes malabarica*: Neriamangalam

Season	Atm. Temperature (°C)	Night Temperature (°C)	Atm.Humidity (Day %)	Atm.Humidity (Night-%)
Summer	31	23	69	73
Monsoon	26	22	84	92
Winter	27	20	74	88

Table: 10
Edaphological data of *Drypetes malabarica*: Neriamangalam

Season	Soil Level	Texture	P^H	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Temp. (°C)	Moisture (%)
Summer	Surface Middle Bottom	Loam Silt clay Silty clay loam	4.6 4.8 4.9	442.2 373.2 313.6	4.8 4.0 3.2	246.4 137.8 64.6	23	16.91
Monsoon	Surface Middle Bottom	Silt clay loam Sandy clay loam Silt loam	4.4 4.7 5.0	458.9 425 227.9	14.74 1.65 5.06	78.1 485.1 141.9	22.5	26.53
Winter	Surface Middle Bottom	Loam Clay loam Silty clay loam	4.9 5.3 4.9	705.6 658.6 420.2	1.5 3.1 5.0	272.2 254.2 118.7	22.7	19.02

Table: 11
Climatological data of *Drypetes malabarica*: Malakkapara

Season	Atm. Temperature (°C)	Night Temperature (°C)	Atm.Humidity (Day-%)	Atm.Humidity (Night-%)
Summer	29	23	58	79
Monsoon	22	19	74	96
Winter	22	17	69	86

Table: 12
Edaphological data of *Drypetes malabarica*: Malakkapara

Season	Soil Level	Texture	PH	N (Kg/h)	P (Kg/ha)	K (Kg/ha)	Temp. (⁰C)	Moisture (%)
Summer	Surface Middle Bottom	Silt loam Silty clay loam Loam	4.7 4.7 5.1	508.0 548.8 727.6	5.5 5.4 1.5	247.5 85.1 118.7	23	12.76
Monsoon	Surface Middle Bottom	Silt clay loam Sand clay loam Silt loam	4.7 4.7 4.7	462 412.7 308.0	71.9 10.23 5.94	121 58.3 196.9	21	26.52
Winter	Surface Middle Bottom	Silty clay loam Sandy clay loam Loamy sandy	5.0 4.9 5.0	708.7 492.4 203.8	4.6 3.8 3.5	196 152.3 160.2	18.7	25.43

Table: 13
Climatological data of D*rypetes malabarica*: Shenduruny WLS

Season	Atm. Temperature (Day -⁰C)	Atm.Temperature (Night-⁰C)	Atm.Humidity (day-%)	Atm.Humidity (Night-%)
Summer	30.2	26.07	58	74
Monsoon	27.3	23.6	75	93
Winter	28.3	22.1	68	82

Table: 14
Edaphological data of *Drypetes malabarica*: Shenduruny WLS

Season	Soil Level	Texture	PH	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Temp. (⁰C)	Moisture (%)
Summer	Surface Middle Bottom	Silty clay loam Silt clay Sandy clay loam	5.6 5.2 5.2	564.5 592.7 492.4	8.7 9.0 40.3	340.5 170.2 131.0	20	19.5
Monsoon	Surface Middle Bottom	Silt clay loam Sandy clay loam Silt loam	5.3 4.6 4.6	449.7 603.7 323.4	35.3 16.1 5.9	487.3 523.6 293.7	22.5	29.76%

Winter	Surface Middle Bottom	Silty clay loam Silt loam Sandy clay loam	5.4 5.3 5.2	940.8 878.1 705.6	13.3 3.6 5.7	131 147.8 299	22.6	25.96%

Table: 15
Climatological data of *Drypetes malabarica*: Kulamavu MPCA

Season	**Atm.Temperature (^{0}C)**	**Night Temperature (^{0}C)**	**Atm. Humidity (Night-%)**
Summer	29.1	24.4	91
Monsoon	27.3	23.2	91
Winter	28.5	22.1	91

Table: 16
Edaphological data of *Drypetes malabarica*: Kulamavu MPCA

Season	**Soil Level**	**Texture**	**P^H**	**N (Kg/ha)**	**P (Kg/ha)**	**K (Kg/ha)**	**Temp. (^{0}C)**	**Moisture (%)**
Summer	Surface Middle Bottom	Silty clay loam Silt clay Sandy loam	4.5 4.6 4.5	564.5 504.9 573.9	1.8 5.0 6.8	121 150.1 172.5	23	19.5
Monsoon	Surface Middle Bottom	Silt clay loam Sandy clay loam Silt loam	4.8 5.0 5.0	637.6 557.5 301.8	33.8 4.4 2.0	636.9 550 1903	21.5	27.67
Winter	Surface Middle Bottom	Silty clay loam Silt loam Sandy clay loam	4.9 4.6 4.9	627.2 439 561.3	2.1 3.4 3.1	142.2 181.4 211.7	22.8	24.56

Table: 17
Vegetative propagation through stem cuttings in *Drypetes 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 ± 0.966	1.60 ±1.275	100
IAA 1000	13	1.70 ± 1.432	1.20 ± 1.412	100
1AA 2000	13	1.30 ± 0.838	1.00 ± 0.852	100
IAA 3000	75	2.00 ± 1.414	2.10 ± 0.447	100
IAA 4000	75	2.00 ± 0.816	4.56 ± 0.988	100
IAA 5000	75	2.50 ± 1.767	6.50 ± 0.707	100
IBA 1000	30	2.00 ± 1.327	1.60 ±1.275	100
IBA 2000	40	2.00 ± 1.60	1.50 ± 1.563	100
IBA 3000	75	2.50 ± 0.967	4.90 ± 0.413	100
IBA 4000	75	2.75 ± 0.635	5.01 ± 0.363	100
IBA 5000	75	4.00 ± 1.514	6.31 ± 1.503	100
NAA 1000	25	1.70 ± 0.871	2.00 ± 1.395	100
NAA 2000	75	2.00 ± 1.118	2.40 ± 1.851	100
NAA 3000	100	2.25 ± 0.866	3.50 ± 1.312	100
NAA 4000	50	1.33 ± 0.966	2.50 ± 0.868	100
NAA 5000	25	2.66 ± 0.68	3.00 ± 0.533	100

Table: 18
Vegetative propagation through air layering in *Drypetes malabarica*

Sl. No.	No. of layers done	Treatment/ Control	Percent of rooting	Survival %
1	4	Control	50	100
2	4	IAA 1000	100	100
3	4	IAA 3000	75	100
4	4	IBA 1000	100	100
5	4	IBA 3000	100	100
6	4	NAA 1000	50	100
7	4	NAA 3000	100	100

Table: 19
Desiccation v/s Moisture content on *Drypetes malabarica* seeds

Seed Type	Condition (Temp./Humidity)	Container	Date of treatment	MC (%)	Germination (%)
Fresh seeds	Open desiccation Room temperature 25±2°C	Open tray	19-11-12	46	50
			20-11-12	43.60	50
			22-11-12	39.05	50
			26-11-12	33.29	25
			30-11-12	31.39	25
			04-12-12	28	20
			06-12-12	25	0

Table: 20
Effect of pre treatments on the seed germination of *Drypetes malabarica*

Pre-treatment given	Date of sowing	MC (%)	Total no. of seeds	No. of seeds germinated	Days taken for germination	Germination (%)
Water soaking-over night	19-11-12	46	4	1	23	25
Hot water soaking (80°C for 5 min)	19-11-12	46	4	0	-	0
Acid scarification (H_2SO_4 for 5 min)	19-11-12	46	4	2	20	50
					31	

Table: 21
Restoration: Details of planting

Site No.	Status	Planting sites	Geographic coordinates	Altitude (m asl)
1.	*In-situ*	Kulamankuzhikudi Neriamangalam Range, Idukki Dt.	*Lat*: 10^0 02′ 35.2″ N. *Long*: 76^0 50′ 9.4″ E.	512 m
2.	*In-situ*	Kulamavu MPCA Nagarampara range, Kotayam Division.	*Lat:* 09^0 48′ 57″ N. *Long:*76^0 53′ 38.3″ E.	890m
3.	*In-situ*	Malakkapara Sholayar Range, Vazhachal Division.	*Lat:* 10^0 17′ 20.4″ N. *Long:* 76^0 48′ 27.9″ E.	849m
4.	*In-situ*	Rosemala Aryankavu Range, Thenmala Division.	*Lat:* 08^0 56′ 14.7″ N. *Long:* 77^0 10′ 19.8″ E.	524 m
5.	*Ex-situ*	KFRI-Arboretum,Peechi, Trichur Dt.	*Lat*: 10° 31' 47" N. *Long*: 76° 22' 7.5" E.	45 m
6.	*Ex-situ*	KFRI-Subcenter, Nilambur, Malappuram Dt.	*Lat*: 11^0 17′ 52.9″ N. *Long*: 76^0 14′ 56.8E.	39m
7.	*Ex-situ*	KFRI-FRC, Velupadam, Trichur Dt.	*Lat*: 10^0 26′ 12.4″ N. *Long*: 76^0 21′ 28.4″ E.	106m

Table: 22

Restoration: Survival, growth and factors affecting mortality of the seedlings planted of *D. malabarica*

Sl. No:	Place of planting	Date of planting	No. of seedlings planted	Average height during planting (cm)	Average height after 6 months (cm)	Average height after 14-16 months (cm)	Survival after 14-16 months (%)	Remarks/Causal factors
I.	***In-Situ* sites**							
1	Neriamangalam	29-06-12	100	26	31	33	80	Wilting due to shortage of rain, Wildlife and human interventions
2	Kulamavu MPCA	30-06-12	100	29	31	33	82	
3	Rosemala	11-07-12	100	22	28	29	74	
4	Malakkapara	20-07-12	100	24	26	28	74	
II.	***Ex-Situ* sites**				**(Data Available for 3 months only**)			
1	FRC-Velupadam	12-06-13	50	32	35	To be recorded	98	Wildlife/Cattle interventions
2	Sub-centre, Nilambur	13-06-13	50	33	37	To be recorded	96	
3	Arboretum,KFRI Peechi.	17-06-13	50	27	33	To be recorded	76	

5.2. *Hydnocarpus macrocarpa*

5.2.1. Population structure

The population structure and floristic diversity analysis in the two study areas viz., **Malakkapara** and **Neriamangalam** are detailed below.

i. Malakkapara

The vegetation profile (Vertical) of the population located at Malakkapara showed the occurrence of major tree species such as *Elaeocarpus tuberculatus* Roxb., *Poeciloneuron indicum* Bedd., *Vateria indica* L., *Holigarna grahamii* (Wight) Kurz, *Bischofia javanica* Blume and *Palaquim ellipticum* (Dalz.) Baill. as first layer/storey, reaching a height range of 31-40 m. The second storey between 21-30 m represented by *Drypetes malabarica* (Bedd.) Airy Shaw, *Hydnocarpus macrocarpa* (Bedd.) Warb., *Knema attenuata* (Hook. f. & Thoms.) Warb., *Mesua thwaitesii* Planch. & Triana, *Paracroton pendulus* (Hassk.) Miq. ssp. *zeylanicus* (Thw.) Balakr. & Chakrab., *Vateria indica* L., *Dysoxylum malabaricum* Bedd. ex Hiern., *Otonephilium stipulaceum* (Bedd.) Radlk., *Macaranga peltata* (Roxb.) Muell.-Arg., *Turpinia malabarica* Gamble, *Mallotus tetracoccus* (Roxb.) Kurz, *Mastixia arborea* (Wight) Bedd., *Walsura trifolia* (A. Juss.), *Aglaia periviridis* Hiern, *Aglaia lawii* (Wight) Saldanha, *Margaritaria indica* Wight, *Terminalia travancorensis* (Gaertn.) Roxb. and *Syzygium gardneri* Thw. The third storey, which is usually less than 20 m is occupied by the small trees such as *Turpinia malabarica* Gamble, *Aglaia lawii* (Wight) Saldanha, *Knema attenuata* (Hook. f. & Thoms.) Warb., *Diospyros paniculata* Dalz., *Macaranga peltata* (Roxb.) Muell.-Arg., *Myristica beddomei* King, *Canarium strictum* Roxb., *Hydnocarpus*

macrocarpa (Bedd.) Warb., *Drypetes malabarica* (Bedd.) Airy Shaw, *Aglaia periviridis* Hiern, *Paracroton pendulus* (Hassk.) Miq. *ssp. zeylanicus* (Thw.) Balakr. & Chakrab., *Otonephilum stipulaceum* (Bedd.) Radlk., *Vateria indica* L., *Trewia nudiflora* L., *Vernonia arborea* Buch.-Ham., *Dimocarpus longan* Lour., *Toona ciliata* Roem., *Dysoxylum malabaricum* Bedd. ex Hiern, *Cyathocalyx zeylanica* Champ. ex Hook. f. & Thoms., *Poeciloneuron indicum* Bedd., *Hydnocapus pentandra* (Buch.-Ham.) Oken, *Walsura trifolia* (A. Juss.) Harms, *Polyalthhia fragrans* (Dalz.) Bedd., *Macaranga indica* Wight, *Canarium strictum* Roxb.. There is also a dense thick of shrubs and climbers including the climbing gymnosperm *Gnetum ula* and below which seedlings of *Arenga wightii* Griff., *Vernonia arborea* Buch.-Ham., *Leea indica* (Burm. f.) Merr., *Antiaris toxicaria* Lesch., *Artocarpus hirsutus* Lam., *Xanthophyllum arnottianum* Wight, *Memecylon umbellatum* Burm.f., *Caryota urens* L., *Baccaurea courtallensis* (Wight) Muell.-Arg., *Strombosia ceylanica* Gard., *Wrightia arborea* (Dennst.) Mabb., *Mangifera indica* L., *Callicarpa tomentosa* (L.) L., *Syzygium laetum* (Buch.-Ham.) Gandhi, *Cipadessa baccifera* (Roth) Miq., and *Mallotus philippensis* (Lam.) Muell.-Arg.

The spatial view of the population site exhibited the arrangement of individuals of *Hydnocarpus macrocarpa* (Bedd.) Warb. in a scattered manner along with their associates. The ground is characterized by slopes, rock boulders, fallen woods, stream etc. The age profile have shown 8 individuals of candidate species consisted of three numbers as set of present (Reproductive phase), four numbers of set of future (pre-reproductive phase) and one number of set of past (post reproductive phase) covering a height range from 10-22 m. The

vertical crown projections had shown the placement of individuals such as *Cullenia exarillata* Robyns, *Turpinia malabarica* Gamble, *Hydnocarpus macrocarpa* (Bedd.) Warb and *Vateria indica* L. just below the tallest individual (Canopy) of *Dysoxylum malabaricum* Bedd. ex Hiern. The horizontal crown projections had displayed the overlapping canopy coverage under the canopy of tallest individual, *D.malabaricum.*

The population structure of *Hydnocarpus macrocarpa* was analyzed by recording GBH, basal area, basal cover, age phases, sex ratios and height of the each individual (Table 23). The floristic diversity analysis covered 41 species of GBH ≥30 cm size of 262 individuals in 5445 sq.m. The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Cullenia exarillata* had highest index value of 0.458679 and thus became the dominant species. Whereas, *Hydnocarpus macrocarpa* represented 11th position with IVI of 0.095819 (Table 24).

The area of occurrence of the species was found to be approximately 12 km^2 and the area of occupancy (area sampled plus non-sampled area) was 0.0045 km^2 and nearly 55 mature trees had seen in the site.

ii. Neriamangalam

The vegetation profile (Vertical) of the population located at Neriamangalam showed the occurrence of major tree species such as *Dipterocarpus indicus* Bedd., *Elaeocarpus tuberculatus* Roxb., *Terminalia bellirica* (Gaertn.) Roxb., *Poeciloneuron indicum* Bedd., *Syzygium gardneri* Thw., *Drypetes malabarica* (Bedd.) Airy

Shaw, *Dysoxylum malabaricum* Bedd. ex Hiern and *Mesua thwaitesii* Planch. & Triana as first layer/storey, reaching a height range of 31-40 m. The second storey between 21-30 m is represented by *Mastixia arborea* (Wight) Bedd., *Gymnacranthera farquhariana* (Hook.f. & Thoms.) Warb., *Paracroton pendulus* (Hassk.) Miq. *ssp. zeylanicus* (Thw.) Balakr. & Chakrab., *Holigarna arnottiana* Hook. f., *Macaranga peltata* (Roxb.) Muell.-Arg., *Holigarna grahamii* (Wight) Kurz, *Vateria indica* L., *Cryptocarya wightiana* Thw. along with the candidate species *Hydnocarpus macrocarpa* (Bedd.) Warb. The third storey, which is usually less than 20 m occupied by the small trees, Shrubs and climbers such as *Hydnocarpus pentandra* (Buch.-Ham.) Oken, *Glochidion zeylanicum* (Gaertn.) A. Juss., *Chionanthus mala-elengi* (Dennst.) P. S. Green, *Croton malabaricus* Bedd., *Xanthophyllum arnottianum* Wight, *Arenga wightii* Griff., *Vernonia arborea* Buch.-Ham., *Memecylon umbellatum* Burm.f., *Caryota urens* L., *Baccaurea courtallensis* (Wight) Muell.-Arg, *Strombosia ceylanica* Gard., *Wrightia arborea* (Dennst.) Mabb., *Mangifera indica* L., *Callicarpa tomentosa* (L.) L., *Syzygium laetum* (Buch.-Ham.) Gandhi, *Mallotus philippensis* (Lam.) Muell.-Arg., *Leea indica* (Burm. f.) Merr., *Schumannianthus virgatus* (Roxb.) Rolfe, *Cipadessa baccifera, Isonandra lanceolata* Wight, *Thottea siliquosa* (Lam.) Ding Hou, *Schefflera wallichiana* (Wight & Arn.) Harms, *Alpinia malaccensis* (Burm. f.) Rosc., *Psychotria flavida* Talbot, *Anamirta cocculus* (L.) Wight & Arn., *Piper barberi* Gamble, *Coscinium fenestratum* (Gaertn.) Colebr., *Cayratia pedata* (Lam.) A. Juss. ex Gagnep., *Momordica sahyadrica* Blume. The herbal layer covered by *Ophiorrhiza* mungos L., *Thottea dinghoui* Swarup., *Smithsonia viridiflora* (Dalz.) Saldanha, *Gastrochilus acaulis* (Lindl.) O. Ktze., *Aeginetia*

pedunculata Wall., *Christisonia calcarata* Wight and *Argostemma courtallense* Arn.

The spatial view of the population site exhibited the arrangement of individuals of *Hydnocarpus macrocarpa* (Bedd.) Warb. in scattered manner along with their associates. The ground is characterized by slopes, rock bolders, fallen woods, stream etc. The age profile have shown 11 individuals of candidate species consisted of 6 numbers as set of present (Reproductive phase), four numbers of set of future (pre-reproductive phase) and one number of set of past (post reproductive phase) covering a height range from 1-28 m. The vertical crown projections had shown the placement of individuals such as *Drypetes malabarica*, *Dimocarpus longan*, *Hydnocarpus macrocarpa* (Bedd.) Warb, *Vernonia arborea, Holigarna grahamii, Diospyros paniculata, Knema attenuata* etc. just below the tallest individual (Canopy) of *Mesua thwaitesii Planch. & Triana*. The horizontal crown projections had displayed the overlapping canopy coverage under the canopy of tallest individual, *M. thwaitesii.*

The population structure of *Hydnocarpus macrocarpa* was analyzed by recording GBH, basal area, basal cover, age phases, sex ratios and height of the each individual (Table 25). The floristic diversity analysis covered 81 species of GBH ≥30 cm size of 268 individuals in 7623sq.m. The aggregated values of relative frequency (rf), relative density (rd) and relative dominance (rD) of each species in the quadrat were worked out and noted that *Poeciloneuron indicum* had highest index value of 0.1675 and thus became the dominant species in the particular quadrat

whereas, the *Hydnocarpus macrocarpa* represented 11th position with IVI of 0.082808 (Table 26).

The area of occurrence of the species in this locality was found to be approximately 3 km^2 and the area of occupancy (area sampled plus non-sampled area) 0.012 km^2 and nearly 150 mature trees can be seen in the site.

Plate 1: ***Hydnocarpus macrocarpa*** (Bedd.) Warb. - **Population Structure**

Habitats: Different views from Neriamangalam forest

Habit showing fruits: Views from Neriamangalam

Habitats: Different views from Malakkapara forest

5.2.2. Population Dynamics

5.2.2.1. Vegetative phenology

Flushing along with matured leaves was noted in October and continued up to February. The young foliage is greenish yellow in color, later turns to light green and finally to dark green. Leaves, alternate, glossy on upper surface when young. New flushing were often infested and fed by caterpillars *Cirrochroa thais* Fabricius (The Tamil Yeoman). Bark is brownish black in colour with rough surface. Leaf flushing also observed at the time of flower bud initiation.

5.2.2.2. Reproductive phenology

The tree is polygamous in nature and therefore male and bisexual plants were separately observed for reproductive phenologies.

Male flower bud initiation was observed along with flushing from January onwards and a peak of flowering was noted in the middle of February. Flowering extended up to middle of March and will complete by last week of April. Around 30-40 days were taken for the development of flower bud to bloom. Matured flower buds start blooming from late evening and extended up to early hours of 1-2 am. Male flowers arranged in fascicles on mature branches, arise as cauliflorus. A single fascicle has 11-38 flowers. Flower buds are spherical, green in colour. Stamens numerous, sepals gradually opens along with petals. Sepals orbicular, green and fleshy sepals 3-4. Petals 2-4, hyaline, ciliate and oblong. A male flower contains 101 anthers which are irregularly arranged along the margin of thalamus. During the peak of flowering insects such as *Apis florae* (Small honey bee)

are seen throughout. Large honey bees, *Apis indica* are also noticed occassionally. In addition, casual and frequent observations of the butterflies such as common Rose (*Pachaliopta aristlochia*), Common Crow (*Euplea core*), *Cirrochroa thais* and un identified moth, sparrows etc. were found visiting the tree.

Female flower bud initiation was noted from February onwards along with flushing and peak flowering noted in the middle of April. Female flowers are comparatively large and fewer than male flowers. Flowers are arranged in fascicles. Female flowers arising from the axils of leaves and flowering numbers are very less. Flower opening noted during midnight and continue till early morning. Stigma receptivity lasts for 10-12 hours. Single female flower lasts for 16-18 hours and turns into brown color. A single fascicle contains 7-8 flowers. Some flowers in the cyme were found gradual wilting and remaining ones involve in actual pollination process and fruit set. Six stigmatic lobes spreading on a thick style. Stigmatic lobes are green, glossy and sticky in nature.

5.2.2.3. Pollen-Ovule (P: O) ratio

As per haemocytometer reading, one anther contained 46,666 pollen grains. It was noted that 101 anthers were present per flower. Therefore, a single flower had around 47,13,266 pollen grains. A female flower had 54 ovules and hence the P: O ratio was worked out as 87,282:1 for the species.

5.2.2.4. Pollen fertility

The acetocarmine staining technique proved that pollen fertility is 100%.

5.2.2.5. Fruit development

Fruit initiation was noted during March and extended up to February (11 months). The young fruits are dark brown in colour and on maturity turned to light brown colour. Around 11 months were taken for fruit development and maturity. It was noticed that around 10% of the fruits were abscised prematurely. Mature fruits have 98-121mm length and 93-122mm breadth and weighs 800-1500gm. The fruit is basically a drupe; globose, thick, dark brown and 35-60 seeds observed in a matured fruit. On attaining 60-70% fruit maturity, 10-20% fruits are get hollowed and seeds are eaten mainly by mammals *Petaurista* sp. Seeds are somewhat hard, having weight of 3-9 gms/seed and it was calculated as 160-220 seeds are present in 1kg. On senescence of ripened fruits, seeds are consumed by ground predators like Porcupine (*Hystrix indica*) etc.

5.2.3. Causal factors for Population Reduction

- The low occurrance of the species / preproductive individuals in the respective communities indicated its fewness among associates.
- Flower wilting and false pollination by around 40-50%.
- Abscition of immature fruits by around 10%.
- Seeds are predated by mammals in the tree itself by around 20%.
- Seed consumption by ground level predators by around 10-20%.
- Short seed viability lead to the poor seedling bank *in situ*.
- Over explitation of matured fruits for seed extraction as NWFP lead poor seed bank *in situ*.

5.2.4. Climatic and Edaphic Factors

Climatological and Edaphological data of the species in respective quadrates in Malakkapara and Neriamangalam were recorded and tabulated. Average value of climatic data such as atmospheric day temperature, canopy temperature, atmospheric humidity, night temperature, night humidity of each season was represented (Table 27 & 29). Similarly, soil samples from three levels (such as surface, 15 cm deep as middle and 30 cm deep as bottom) were collected and data on texture, pH, dissolved minerals, nutrients etc. were also recorded. Soil moisture content and soil temperature of each season were also noted to understand the edaphic environment of species (Table 28 & 30).

Plate 2: *Hydnocarpus macrocarpa* (Bedd.) Warb. **- Population Dynamics**

Flushing: Different views

Views of caterpillar infestation

Adult moth: *Cirrochroa thais* Fabricius

Views of male and bisexual flowers in fascicles

Fruiting primordia

Views of fruit development, senescence and seed predated fruit shell

Soil smple collectionn

5.2.5. Conservation Strategies

5.2.5.1. Vegetative propagation

Propagation through stem cuttings and air layering were tried for multiplication. Stem cuttings along with auxins such as IAA, IBA and NAA of different concentrations were attempted. In all cases, no promising results have been achieved. However, juvenile stem cuttings taken from 2 years old saplings showed 66% success with the aid of IBA 5000ppm within 64-81 days. Whereas, 36% success noted in control (Table 31) after 2-3 months. In air layering, young plants of 2 years old showed 100% success with the aid of NAA 3000ppm within 48-132 days. Whereas, control resulted 25% success after 4-5 months (Table 32). The plant has also exhibited reiterating ability which ensures the growth of the parent plants after the separation of rooted portions from the stock.

5.2.5.2. Seed propagation

The ripened fruits were collected and removed the fleshy fruit rind. The processed seeds were analyzed for initial moisture content. Seeds were subsequently surface dried and kept for storage and germination studies.

The fresh seeds with a moisture content of 45% resulted 85% germination within 8-10 days where river sand is used as sowing medium in the nursery. In normal conditions, seeds lost its viability within one week with critical moisture content 17% along with germination 33% under room conditions. The type of seed germination is epigeal. The seeds had shown desiccation and chilling sensitivity towards storage temperature conditions. Therefore the seeds were categorized in the recalcitrant group.

For extending the viability of the seeds, different storage trials were tried using different containers at different storage conditions. The results (Table 33) indicated that the seeds stored in closed polycarbonate bottles at 20±2°C in Seed bank conditions extended the viability upto 64 days with 20% germinability compared to other storage trials. Therefore, the standardized method of storage can be adopted for germplasm preservation of the species.

Plate 3: ***Hydnocarpus macrocarpa*** (Bedd.) Warb. – **Conservation**


Views of rooting success: stem cuttings and layered plants at nursery

Air layering success

Matured fruits

Processed seeds

Seed germination in lab and nursery

Seed germination in mist chamber


Views of planting stock in the nursery

5.2.6. Restoration

Six natural evergreen ecosystems in the Western Ghats of Kerala region were selected for *in situ* recovery planting. In addition, three sites were also selected for *ex situ* planting. (Table 34 and 35).

A total of 1400 seedlings were reintroduced in six *in situ* sites of the species. Fully established 2-yr old polybagged seedlings having an average height of 54-77cm were transported from the nursery to the planting sites. Pits were prepared in tune with canopy gaps in the population areas. Each seedling was tag-marked for monitoring. Planting of the seedlings was done during June –November months. Further, 375 seedlings were also casualty planted *in situ*. The periodic monitoring on the establishment and survival performance of the seedlings was carried out in half yearly basis. Caterpillar feeding of growing stem tip of seedlings was noted in few planted sites.

1. Kulamavu MPCA

Two hundred and fifty seedlings of 1.0 - 1.5 years old were planted in the site. The mean height of seedlings during planting was 58cm and the maximum height recorded was 102cm. The site recorded with low survival rate of 39% as compared with other *in situ* sites. The average height of 66cm and a maximum height of 89cm after 1.5 years of field planting. New shoot growth of the seedlings were arrested due to caterpillar feeding and become reduced the height increment. Shortage of SW monsoon, elephant trampling in the planting area etc. contributed to the mortality of seedlings in the site.

2. Neriamangalam

Two hundred and fifty seedlings of 1.0 - 1.5 years old were planted in the site. The mean height of seedlings during planting was 54cm and the maximum height recorded was 101cm. The seedlings showed 73% survival on evaluation. The average height of 77cm and a maximum height of 130cm reached after 1.5 years of field planting were recorded. It was noted that the seedlings had slow growth in the site. The leaves of some seedlings were wilted due to the lack of rain and also the over growth of *Schumanniathus virgatus,* a weed plant which reduced the growth of seedlings. It was also noted that the terminal growing bud of the seedlings are either cut down or eaten by caterpillars.

3. Rosemala

Two hundred and fifty seedlings of 1.0 - 1.5 years old were planted in the site. The mean height of seedlings during planting was 68cm along with a maximum height recorded was 107cm. The site was recorded a moderate survival rate of 61%. The average height of 71cm and a maximum height of 115 cm after 1.5 years of field planting were recorded. Wild life interventions and reduction in SW monsoon found affected the survival of seedlings in the site.

4. Malakkappara

Two hundred and fifty seedlings of 1.0 - 1.5 years old were planted at Pathadipalam, near Malakkapara. The mean height of seedlings during planting was 69cm and the maximum height recorded was 115cm. The site recorded a maximum survival rate of 71% as compared with other sites. Average height was noted

as 82cm and maximum height reached upto 121cm. The reduction in SW monsoon, Wildlife interventions and feeding of leaves by caterpillars has affected the survival of seedlings in the site.

5. Kallar

Two hundred eedlings of 1.0 - 1.5 years old were panted at Kallar forest area, Golden valley near Mottamoodu. The mean height of the seedlings during planting was 63cm along with a maximum height of 125cm. The moderately, low growth rate was noticed due to lack of rain throughout the period and the seedlings offered a low rate of survival, 55%. The average seedling height was 66 cm and the maximum height recorded was 114 cm. New shoot growth of the seedlings were arrested due to caterpillar feeding and height increment become reduced.

6. Periya

Two hundred seedlings of 1.0 - 1.5 years old were planted Wayanad MPCA at Periya Forest Range. The mean height of the seedlings during planting was 75cm and the maximum height 125cm. The seedlings showed 67% survival after 1 year. The mean height of seedlings was 76 cm and the maximum height recorded as 119cm. The new shoot growth of the seedlings was arrested due to caterpillar feeding and therby reduced the height increment.

Plate 4: ***Hydnocarpus macrocarpa*** (Bedd.) Warb. - **Restoration**

Views of seedling transportation, planting and metal display board: Kulamavu MPCA

Views at Kallar

Views at Malakkapara

Views at Neriamangalam

A total of 150 seedlings of the species were planted in three *ex situ* viz.,

1. KFRI Arboretum

Fifty seedlings of *H.macrocarpa* were planted at KFRI Arboretum, Peechi. The mean height of the seedlings during planting was 69cm along with a maximum height of 108cm. The seedlings showed a survival rate of 80% after 1.5 year of field planting with mean seedling height of 96 cm and the maximum height 161cm. A few seedlings were terminally damaged by varied physical interventions.

2. FRC Velupadam

Fifty seedlings were planted at FRC Velupadam. The mean height of seedlings during planting was 74cm with a maximum height 120cm. The seedling showed a good survival rate of 88% after 1.5 years of planting with average seedling height of 74cm and maximum height into 112cm. The new shoot growth of the seedlings was arrested due to caterpillar feeding and thereby reduced the height increment. Browsing by spotted deer has affected the survival of seedlings in the site.

3. Sub centre, Nilambur

Fifty seedlings were planted in the site. The mean height of seedlings during planting was 77cm and the maximum height was 105cm. The maximum seedling survival of 92% achieved along with average height of 83cm and maximum height of 121cm. The apical growing buds were found rarely fed by catrepillars.

Plate 5: ***Hydnocarpus macrocarpa*** (Bedd.) Warb. – **Restoration**

Views at Rosemala

Views at Wayanadu MPCA

Different views of *ex situ* seedling planting and evaluation: FRC Velupadam:

Different views of *ex situ* seedling planting and evaluation: KFRI Arboretum:

Different views of *ex situ* seedling planting and evaluation: Sub centre Nilambur

Table: 23
Population Structure of *Hydnocarpus macrocarpa*: Malakkapara
(List of individuals with G≥30 cm represented**)**

Sl. No.	GBH (cm)	r (cm)	Basal area (cm^2)	Basal Cover (m)	Age Phase	First branching seen at (m)	Height of Stand (m)
1	146	23.25	1697.37	10	Set of Present	5.0	22
2	115	18.31	1052.70	8	Set of Present	4.0	18
3	50	7.96	198.95	7	Set of future	3.0	13
4	85	13.54	575.66	8	Set of future	2.0	13
5	167	26.59	2220.06	9	Set of present	4.0	18
6	98	15.61	765.13	8	Set of future	3.0	16
7	175	27.87	2438.95	11	Set of past	4.5	20
8	42	6.69	140.53	5	Set of future	2.5	10

Table: 24
Floristic diversity/Important Value Index of *Hydnocarpus macrocarpa*: Malakkapara
(List of individuals with G≥ 30 cm represented)

Sl. No	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Cullenia exarillata*	Bombacaceae	0.0543	0.0877	0.3165	0.4586
2	*Palaquium ellipticum*	Sapotaceae	0.0434	0.1374	0.1717	0.3526
3	*Aglaia lawii*	Meliaceae	0.0434	0.1259	0.0544	0.2238
4	*Vateria indica*	Dipterocarpaceae	0.0434	0.0496	0.0502	0.1433
5	*Turpinia malabarica*	Staphyleaceae	0.0326	0.0458	0.0418	0.1202
6	*Myristica beddomei*	Myristicaceae	0.0543	0.0381	0.0252	0.1177
7	*Paracroton pendulus ssp. Zeylanicus*	Euphorbiaceae	0.0434	0.0343	0.0255	0.1034
8	*Poeciloneuron indicum*	Clusiaceae	0.0326	0.0496	0.0169	0.0991
9	*Meiogyne pannosa*	Annonaceae	0.0326	0.0572	0.0067	0.0966
10	*Dysoxylum malabaricum*	Meliaceae	0.0326	0.0114	0.0518	0.0959
11	*Hydnocarpus macrocarpa*	Flacourtiaceae	0.0326	0.0343	0.0288	0.0958
12	*Otonephilium stipulaceum*	Sapindaceae	0.0434	0.0343	0.0095	0.0873
13	*Mesua ferrea*	Clusiaceae	0.0326	0.0229	0.0208	0.0763
14	*Oreocnide integrifolia*	Urticaceae	0.0326	0.0381	0.0032	0.0740

15	*Mesua thwaitesii*	Clusiaceae	0.0217	0.0076	0.0417	0.0710
16	*Holigarna arnottiana*	Anacardiaceae	0.0108	0.0038	0.0460	0.0606
17	*Reinwardtiodendron anamalaiense*	Meliaceae	0.0326	0.0229	0.0044	0.0599
18	*Glochidion ellipticum*	Euphorbiaceae	0.0326	0.0152	0.0019	0.0498
19	*Antidesma montanum*	Euphorbiaceae	0.0326	0.0114	0.0034	0.0475
20	*Diospyros paniculata*	Ebenaceae	0.0217	0.0190	0.0060	0.0468
21	*Drypetes venusta*	Euphorbiaceae	0.0217	0.0152	0.0077	0.0447
22	*Melicope lunu-ankenda*	Rutaceae	0.0217	0.0114	0.0099	0.0431
23	*Syzygium gardneri*	Myrtaceae	0.0217	0.0152	0.0048	0.0418
24	*Calophyllum polyanthum*	Clusiaceae	0.0108	0.0076	0.0228	0.0413
25	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.0217	0.0076	0.0109	0.0403
26	*Syzygium laetum*	Myrtaceae	0.0217	0.0076	0.0007	0.0301
27	*Knema attenuata*	Myristicaceae	0.0217	0.0076	0.0006	0.0299
28	*Phoebe lanceolata*	Lauraceae	0.0108	0.0114	0.0014	0.0237
29	*Toona ciliata*	Meliaceae	0.0108	0.0038	0.0053	0.0200
30	*Dimorphocalyx glabellus var. lawianus*	Euphorbiaceae	0.0108	0.0076	0.0011	0.0196
31	*Canarium strictum*	Burseraceae	0.0108	0.0076	0.0010	0.0195
32	*Aglaia periviridis*	Meliaceae	0.0108	0.0076	0.0006	0.0191
33	*Actinodaphne malabarica*	Lauraceae	0.0108	0.0076	0.0005	0.0190
34	*Callicarpa tomentosa*	Verbenaceae	0.0108	0.0076	0.0003	0.0188
35	*Vernonia arborea*	Asteraceae	0.0108	0.0038	0.0025	0.0172
36	*Agrostistachys borneensis*	Euphorbiaceae	0.0108	0.0038	0.0003	0.0150
37	*Aglaia tomentosa*	Meliaceae	0.0108	0.0038	0.0002	0.0149
38	*Artocarpus heterophyllus*	Moraceae	0.0108	0.0038	0.0002	0.0149
39	*Glochidion zeylanicum var. zeylanicum*	Euphorbiaceae	0.0108	0.0038	0.0002	0.0149
40	*Persea macrantha*	Lauraceae	0.0108	0.0038	0.0002	0.0149
41	*Caryota urens*	Arecaceae	0.0108	0.0038	0.0001	0.0148

Table: 25
Population Structure of *Hydnocarpus macrocarpa*:
Neriamangalam
(List of individuals with G≥30 cm represented**)**

Sl. No.	**GBH (cm)**	**r (cm)**	**Basal area (cm^2)**	**Basal Cover (m)**	**Age Phase**	**First branching seen at (m)**	**Height of Stand (m)**
1	100	15.92	795.82	10	Set of Present	6.0	14
2	220	35.03	3972.80	15	Set of past	8.0	28

3	70	11.15	390.37	6	Set of future	3.0	14
4	123	19.59	1205.03	8	Set of present	2.5	22
5	130	20.70	1345.46	13	Set of present	6.0	15
6	110	17.52	963.82	10	Set of present	4.0	12
7	102	16.24	828.14	12	Set of present	5.0	24
8	91	14.49	659.27	7	Set of future	3.0	18
9	68	10.83	368.29	8	Set of future	3.0	10
10	36	5.73	103.10	4	Set of future	3.0	01
11	140	22.29	1560.09	8	Set of present	4.0	23

Table: 26
Floristic diversity/Importance Value Index of *Hydnocarpus macrocarpa*: Neriamangalam
(List of individuals with G≥ 30 cm represented)

Sl. No	Name of species	Family	rf (%)	rd (%)	rD (%)	IVI
1	*Poeciloneuron indicum*	Clusiaceae	0.0205	0.0298	0.1171	0.1675
2	*Bombax ceiba*	Bombacaceae	0.0068	0.0037	0.1316	0.1422
3	*Turpinia malabarica*	Staphyleaceae	0.0342	0.0783	0.0289	0.1415
4	*Dysoxylum malabaricum*	Meliaceae	0.0273	0.0261	0.0493	0.1028
5	*Otonephelium stipulaceum*	Sapindaceae	0.0342	0.0373	0.0244	0.0960
6	*Hopea parviflora*	Dipterocarpaceae	0.0068	0.0074	0.0817	0.0960
7	*Vernonia arborea*	Asteraceae	0.0205	0.0298	0.0437	0.0941
8	*Syzygium gardneri*	Myrtaceae	0.0205	0.0186	0.0514	0.0906
9	*Elaeocarpus tuberculatus*	Elaeocarpaceae	0.0273	0.0186	0.0433	0.0894
10	*Mesua thwaitesii*	Clusiaceae	0.0205	0.0223	0.0402	0.0831
11	*Hydnocarpus macrocarpa*	Flacourtiaceae	0.0205	0.0410	0.0212	0.0828
12	*Hydnocarpus pentandra*	Flacourtiaceae	0.0273	0.0298	0.0228	0.0800
13	*Reinwardtiodendron anamalaiense*	Meliaceae	0.0205	0.0335	0.0117	0.0658
14	*Knema attenuata*	Myristicaceae	0.0273	0.0223	0.0138	0.0636
15	*Aglaia lawii*	Meliaceae	0.0136	0.0298	0.0180	0.0615
16	*Polyalthia fragrans*	Annonaceae	0.0205	0.0149	0.0226	0.0580
17	*Diospyros sylvatica*	Ebenaceae	0.0205	0.0186	0.0158	0.0550
18	*Croton malabaricus*	Euphorbiaceae	0.0136	0.0335	0.0050	0.0522
19	*Myristica beddomei*	Myristicaceae	0.0205	0.0223	0.0093	0.0522
20	*Margaritaria indica*	Euphorbiaceae	0.0068	0.0261	0.0165	0.0495
21	*Drypetes malabarica*	Euphorbiaceae	0.0136	0.0223	0.0104	0.0465
22	*Pterospermum*	Sterculiaceae	0.0068	0.0074	0.0292	0.0435

	reticulatum					
23	*Gymnacranthera farquhariana*	Myristicaceae	0.0068	0.0149	0.0212	0.0429
24	*Macaranga peltata*	Euphorbiaceae	0.0205	0.0149	0.0068	0.0423
25	*Aglaia perviridis*	Meliaceae	0.0205	0.0111	0.0099	0.0416
26	*Mitragyna tubulosa*	Rubiaceae	0.0136	0.0149	0.0118	0.0404
27	*Chionanthus mala-elengi*	Oleaceae	0.0136	0.0186	0.0078	0.0402
28	*Vateria indica*	Dipterocarpaceae	0.0205	0.0111	0.0053	0.0370
29	*Antidesma montanum*	Euphorbiaceae	0.0136	0.0186	0.0043	0.0366
30	*Holigarna grahamii*	Anacardiaceae	0.0136	0.0111	0.0102	0.0350
31	*Aporosa cardiosperma*	Euphorbiaceae	0.0205	0.0111	0.0010	0.0328
32	*Glochidion ellipticum*	Euphorbiaceae	0.0136	0.0111	0.0070	0.0319
33	*Xanthophyllum arnottianum*	Polygalaceae	0.0136	0.0149	0.0010	0.0297
34	*Paracroton pendulus ssp. zeylanicus*	Euphorbiaceae	0.0068	0.0186	0.0041	0.0296
35	*Alstonia scholaris*	Apocynaceae	0.0136	0.0111	0.0047	0.0296
36	*Cryptocarya wightiana*	Lauraceae	0.0136	0.0074	0.0069	0.0281
37	*Trichilia connaroides*	Meliaceae	0.0136	0.0111	0.0030	0.0279
38	*Baccaurea courtallensis*	Euphorbiaceae	0.0136	0.0111	0.0020	0.0269
39	*Clausena indica*	Rutaceae	0.0136	0.0111	0.0011	0.0260
40	*Spondias indica*	Anacardiaceae	0.0136	0.0074	0.0045	0.0257
41	*Toona ciliata*	Meliaceae	0.0136	0.0074	0.0040	0.0251
42	*Diospyros paniculata*	Ebenaceae	0.0136	0.0074	0.0030	0.0242
43	*Myristica malabarica*	Myristicaceae	0.0136	0.0074	0.0019	0.0231
44	*Cinnamomum malabatrum*	Lauraceae	0.0136	0.0074	0.0013	0.0225
45	*Mastixia arborea*	Cornaceae	0.0068	0.0074	0.0071	0.0214
46	*Glochidion zeylanicum var. zeylanicum*	Euphorbiaceae	0.0068	0.0074	0.0069	0.0213
47	*Dimorphocalyx glabellus var. lawianus*	Euphorbiaceae	0.0068	0.0074	0.0049	0.0192
48	*Mallotus philippensis*	Euphorbiaceae	0.0068	0.0074	0.0026	0.0169
49	*Dipterocarpus indicus*	Dipterocarpaceae	0.0068	0.0037	0.0058	0.0164
50	*Dalbergia latifolia*	Fabaceae	0.0068	0.0074	0.0018	0.0162
51	*Polyalthia fragrans*	Annonaceae	0.0068	0.0037	0.0050	0.0156
52	*Litsea keralana*	Lauraceae	0.0068	0.0074	0.0011	0.0154
53	*Pterygota alata*	Sterculiaceae	0.0068	0.0074	0.0007	0.0150
54	*Terminalia paniculata*	Combretaceae	0.0068	0.0037	0.0032	0.0138
55	*Dimocarpus longan*	Sapindaceae	0.0068	0.0037	0.0031	0.0137

56	*Sapindus trifoliatus*	Sapindaceae	0.0068	0.0037	0.0026	0.0132
57	*Terminalia bellerica*	Combretaceae	0.0068	0.0037	0.0021	0.0126
58	*Cassia fistula*	Caesalpiniaceae	0.0068	0.0037	0.0020	0.0126
59	*Flacourtia montana*	Flacourtiaceae	0.0068	0.0037	0.0019	0.0125
60	*Memecylon sp.*	Melastomataceae	0.0068	0.0037	0.0018	0.0123
61	*Hopea racophloea*	Dipterocarpaceae	0.0068	0.0037	0.0015	0.0121
62	*Polyathia fragrans*	Annaonaceae	0.0068	0.0037	0.0014	0.0120
63	*Litsea keralana*	Lauraceae	0.0068	0.0037	0.0013	0.0118
64	*Holigarna arnottiana*	Anacardiaceae	0.0068	0.0037	0.0012	0.0117
65	*Artocarpus hirsutus*	Moraceae	0.0068	0.0037	0.0011	0.0117
66	*Grewia tiliifolia*	Tiliaceae	0.0068	0.0037	0.0011	0.0117
67	*Xanthophyllum arnotianum*	Polygalaceae	0.0068	0.0037	0.0010	0.0115
68	*Ficus sp.*	Moraceae	0.0068	0.0037	0.0009	0.0115
69	*Vitex altissima*	Verbenaceae	0.0068	0.0037	0.0007	0.0113
70	*Terminalia bellirica*	Combretaceae	0.0068	0.0037	0.0006	0.0112
71	*polyalthia coffeoides*	Annonaceae	0.0068	0.0037	0.0004	0.0109
72	*Litsea coriacea*	Lauraceae	0.0068	0.0037	0.0003	0.0109
73	*Caryota urens*	Arecaceae	0.0068	0.0037	0.0003	0.0109
74	*Persea macrantha*	Lauraceae	0.0068	0.0037	0.0002	0.0108
75	*Holoptelea integrifolia*	Ulmaceae	0.0068	0.0037	0.0002	0.0108
76	*Glyptopetalum zeylanicum*	Celastraceae	0.0068	0.0037	0.0002	0.0108
77	*Semecarpus travancorica*	Anacardiaceae	0.0068	0.0037	0.0002	0.0108
78	*Xanthophyllum arnottianum*	Polygalaceae	0.0068	0.0037	0.0002	0.0107
79	*Memecylon umbellatum*	Melastomataceae	0.0068	0.0037	0.0001	0.0107
80	*Coffea arabica*	Rubiaceae	0.0068	0.0037	0.0001	0.0107
81	*Leea indica*	Leeaceae	0.0068	0.0037	0.0001	0.0107

Table: 27

Climatological data of *Hydnocarpus macrocarpa*: Malakkapara

Season	**Atm. Temperature (ºC)**	**Night Temperature (ºC)**	**Atm. Humidity (Day-%)**	**Atm. Humidity (Night-%)**
Summer	29	23	58	79
Monsoon	22	19	74	96
Winter	22	17	69	86

Table: 28

Edaphological data of *Hydnocarpus macrocarpa*: Malakkapara

Season	Soil Level	Texture	PH	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Temp. (°C)	Moisture (%)
Summer	Surface Middle Bottom	Silt loam Sandy loam Loam	5.3 4.5 5.3	508 492.4 639.7	1.3 4.3 2.1	174.7 43 38.1	22	42.39
Monsoon	Surface Middle Bottom	Silty clay loam Silt clay Silt clay loam	4.7 4.9 5.1	779.24 511.28 520.52	68.86 25.08 11.22	122.10 366.30 542.30	20	30.35
Winter	Surface Middle Bottom	Silt clay Loam Silt loam	5.2 5.2 5.0	448.4 435.9 323	34.2 33.5 26.3	207.2 67.2 60.5	18.7	35.26

Table: 29

Climatological data of *Hydnocarpus macrocarpa*: Neriamangalam

Season	Atm.Temperature (°C)	Night Temperature (°C)	Atm. Humidity (Day-%)	Atm. Humidity (Night-%)
Summer	31	23	69	73
Monsoon	26	22	84	92
Winter	27	20	74	88

Table: 30

Edaphological data of *Hydnocarpus macrocarpa*: Neriamangalam

Season	Soil Level	Texture	PH	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	Temp. (°C)	Moisture (%)
Summer	Surface Middle Bottom	Silt loam Silt loam Silty Clay loam	4.6 4.8 5.1	366.52 360.36 354.20	52.25 23.43 9.24	1203.40 216.70 114.40	23	15.52
Monsoon	Surface Middle Bottom	Silt clay loam Sandy clay loam Silt loam	5.4 5.1 5.4	545.16 609.84 505.12	44.22 32.67 4.62	301.40 121.00 1566.40	22.5	26.53

Winter	Surface Middle Bottom	Silt clay Silty clay loam Clay loam	5.1 4.7 5.1	508 539.4 407.7	3.9 3.4 5.8	141.1 146.7 65.3	22.2	21.63

Table: 31
Vegetative propagation through stem cuttings in *Hydnocarpus macrocarpa*

Treatment (ppm)	Rooting (%)	Mean No of Roots (Mean ± SD) (cm)	Mean Length of Roots (Mean ± SD) (cm)	Survival of Ramets (%)
Control	36	1.25 ± 0.5	7.20 ± 2.28	50
IAA3000	16	1.00 ± 0	1.50 ± 0	0
IAA4000	16	1.00 ± 0	1.50 ± 0	100
IAA5000	32	1.00 ± 0	2.25 ± 0.354	100
IAA 6000	Nil	Nil	Nil	0
IAA 8000	16	4.00 ± 0	4.875 ± 1.89	50
IBA3000	16	1.00 ± 0	1.50 ± 0	66
IBA4000	16	1.00 ± 0	1.30 ± 0	50
IBA5000	66	3.50 ± 2.516	7.53 ± 3.23	100
IBA 6000	60	1.67 ± 0.58	6.70 ± 4.49	100
IBA 8000	50	2.67 ± 1.53	1.34 ± 0.4	50
NAA3000	50	1.66 ± 0.577	4.40 ± 0.742	66
NAA4000	50	2.50 ± 2.121	7.10 ± 1.851	0
NAA5000	16	3.00 ± 0	7.67 ± 0.76	100
NAA 6000	60	1.67 ± 0.58	10.1 ± 5.95	100
NAA 8000	Nil	Nil	Nil	Nil

Table: 32
Vegetative propagation through air layering in *Hydnocarpus macrocarpa*

Sl. No.	No. of layers done	Treatment/ Control	Percent of rooting	Survival %
1	4	Control	25	100
2	4	IAA 1000	25	100
3	4	IAA 3000	50	50
4	4	IAA 5000	50	50
5	4	IBA 1000	50	50
6	4	IBA 3000	25	100
7	4	IBA 5000	50	50
8	4	NAA 1000	50	100
9	4	NAA 3000	100	75
10	4	NAA 5000	50	50

Table: 33

Effect of storage conditions on the moisture content and germination of *Hydnocarpus macrocarpa* seeds

Sl. No	Seed type	Container	Condition Temp./Humidity	Moisture(M) Germination (G) %	Moisture content/Germination (%) after storage															
					09-04-13	10-04-13	11-04-13	12-04-13	13-04-13	14-04-13	15-04-13	16-04-13	17-04-13	09-05-13	10-05-13	13-05-13	14-05-13	06-06-13	11-06-13	02-07-13
1	Fresh	Open Plastic Tray	Ambient (25°C, RH 50-60%)	M	45	43	39	37	30	24	20	17	15							
				G	85	80	75	66	50	36	34	33	0							
2	”	Closed Bottle	Ambient (25°C, RH 50-60%)	M	45									43				39		
				G	80									70				65		
3	”	Closed Poly.bag	Ambient (25°C, RH 50-60%)	M	45									41				40		
				G	75									60				50		
4	”	Closed Poly.bag in sawdust	Ambient (25°C, RH 50-60%)	M	45									34				32		
				G	75									50				30		
5	”	Open Plastic Tray	16°C RH:- 45%	M			55					17				14			09	08
				G			0					0				0			0	0
6	”	Closed Bottle	16°C RH:- 45%	M			55							51				54		
				G			30							17				17		
7	”	Closed Poly.bag	16°C RH:- 45%	M			55							54				53		
				G			40							0				0		
8	”	Closed Poly.bag in sawdust	16°C RH:- 45%	M			55							51				48		
				G			33							0				0		
9	„	Open Plastic Tray	20°C RH:-70%	M	45	28						25							18	17
				G	0	0						17							0	0
10	”	Closed Bottle	20°C RH:-70%	M	45									43					39	
				G	70									50					20	
11	„	Closed Poly.bag	20°C RH:-70%	M	45							45							46	
				G	20							17							0	
12	”	Closed Poly.bag in sawdust	20°C RH:-70%	M	45							39							28	
				G	0							0							0	

Table 34
Restoration: Details of planting

Site No.	Status	Planting sites	Geographic coordinates	Altitude (m asl)
1.	*In-situ*	Kulamankuzhikudi Neriamangalam Range, Idukki Dt.	Lat: 10^0 02′ 35.2″ N Long: 76^0 50′ 9.4″ E	512 m
2.	*In-situ*	Kulamavu MPCA Nagarampara range, Kotayam Division.	Lat: 09^0 48′ 57″, N. Long: 76^0 53′ 38.3″ E.	890m
3.	*In-situ*	Malakkapara Sholayar Range, Vazhachal Division.	Lat: 10^0 17′ 20.4″N. Long: 76^0 48′ 27.9″ E.	849m
4.	*In-situ*	Rosemala Aryankavu Range, Thenmala Division.	Lat: 08^0 56′ 14.7″N. Long: 77^0 10′ 19.8″ E.	524 m
5.	*In-situ*	Wayanadu MPCA, Chandanathode, Periya Range, N.Wayanad Forest Division.	Lat: 11^0 51′ 3.19″, N. Long: 75^0 48′ 5.94″ E.	800 m
6.	*In-situ*	Kallar,Mottamoodu, Palode Range Thiruvanathapuram Division	Lat: 08^0 43′ 23.75″N. Long: 77^0 07′ 33.38″E.	400 m
7.	*Ex-situ*	KFRI-Arboretum,Peechi, Trichur Dt.	Lat: 10° 31' 47" N. Long: 76° 22' 7.5" E.	45 m
8.	*Ex-situ*	KFRI-Subcenter, Nilambur, Malappuram Dt.	Lat: 11^0 17′ 52.9″N. Long: 76^0 14′ 56.8E.	39m
9.	*Ex-situ*	KFRI-FRC, Velupadam, Trichur Dt.	Lat: 10^0 26′ 12.4″N. Long: 76^0 21′ 28.4E.	106m

Table: 35
Restoration of *Hydnocarpus macrocarpa*:
Establishment, growth and factors affecting seedling survival

Place of planting	Date of planting	No. of seedlings planted	Average height during planting(cm)	Average height after 6 months (cm)	Average height after 12-16 months(cm)	Survival after 12-16 months (%)	Rema fa
***In-Situ* sites**							
Kulamavu MPCA	29-06-12	250	58	65	66	39	Wilting
Neriamangalam	28-06-12 29-06-12	250	54	65	77	73	shortage human
Rosemala	11-07-12	250	68	69	71	61	interven
Malakkapara	20-07-12	250	69	74	82	71	caterpill
Kallar	20-10-12	200	63	65	66	52	infestati
Periya	08-11-12	200	75	76	79	67	
***Ex-Situ* sites**							
KFRI Arboretum	03-08-12	50	69	78	96	80	
FRC Velupadam	08-08-12	50	73	75	77	94	Wildlife interven
Sub centre, Nilambur	13-08-12	50	77	81	83	92	wilting

6. Discussion and Conclusion

The population structural studies conducted in *Drypetes malabarica* in the four forest areas viz., Neriamangalam, Malakkapara, Shendurny and Kulamavu MPCA has revealed much similarities and resemblances in the distribution pattern, habitat preferences, associate species in different sites. Generally, the species is distributed in the evergreen forests at an altitude above 500m asl. The associated species such as, *Elaeocarpus tuberculatus, Vateria indica, Poeciloneuron indicum, Holigarna grahamii*, (Neriamangalam); *Palaquium ellipticum, Cullenia exarillata, Myristica beddomei, Mesua ferrea* var. *ferrea, Semecarpus travancoricum* (Malakkapara); *Lophopetalum wightianum.,Hopea racophloea, Gluta travancorica* (Shenduruny); *Calophyllum polyanthum, Elaeocarpus tuberculatus, Dimocarpus longan* etc. (Kulamavu MPCA) found as top layer/canopy species at 31-40m. Whereas, *Drypetes malabarica* noted as a sub-canopy, second – third layer species at 07-30 m height range along with its associated species such as *Hydnocarpus macrocarpa.*, *Knema attenuata,* small trees of *Mesua thwaitesii* (Neriamangalam), *Myristica beddomei, Aglaia periviridis*, small trees of *Cullenia exarillata*, (Malakkapara), *Pterospermum diversifolium, Flacourtia montana, Hydnocarpus pentandra*, *Myristica beddomei* (Shenduruny), *Diospyros paniculata, Gordonia obtusa, Mastixia arborea, Turpinia malabarica* etc. at Kulamavu MPCA.

The spatial occurrence of *Drypetes malabarica* has been displayed scattered distribution pattern in adjacent to water course indicating the habitat specificity of the species. The age wise distribution of the populations in the enumerated quadrats at four sites showed below average (40%) number of pre-reproductive

individuals pointing towards the moderately low percent of regeneration potential of the species. The age profile of the populations was revealed that the individuals of *D. malabarica* start flowers when the gbh attained around 50-70 cm along with 10-12 m height range. The species diversity analysis of *D. malabarica* in each site (five quadrats of each sized 33x33m^2 covering a total enumerated area of 5445m^2 per site) exhibited comparatively lower dominant nature of the *D.malabarica* among the associates. In Neriamangalam, out of 57 species enumerated in five quadrats, *D.malabarica* attained with 13th relative position. Further, the area of occurrence of the species calculated into 3km^2 and area of occupancy into 0.0036 km^2 along with 50 mature individuals in the particular forest segment. Similarly at Malakkapara, out of 69 species enumerated in five quadrats, *D.malabarica* attained with 11th relative position. The area of occurrence of the species calculated into 30km^2 and area of occupancy into 0.011 km^2 along with 150 mature individuals in the particular forest segment. Whereas, at Shenduruny, among 63 associated species identified, *D.malabarica* attained at 26th relative position. The area of occurrence calculated into 75km^2 and area of occupancy into 0.0047 km^2 along with 65 mature individuals in the particular forest segment. At Kulamavu MPCA, among 54 associated species, *D.malabarica* attained with 11th relative position. Further, the area of occurrence of the species calculated into 1.7 km^2 and area of occupancy into 0.015 km^2 with 200 mature individuals in the particular forest segment. The aggregation in area of occurrence and area occupancy of the species in four study sites thus showed an extent of species in 110km^2 with 465 mature individuals under area of occupancy within 0.0343km^2. These values are found falling under 'Endangered' (EN) threat category of IUCN wherein the extent of

species had given @ 5000km^2 with less than 2500 mature individuals under an area of occupancy of 500km^2.

The population structural studies of *Hydnocarpus macrocarpa* in the two study areas viz., Malakkapara and Neriamangalam projected much resemblances and similarities in distribution pattern and habitat requirements. The species distribution noted in the evergreen/ semi evergreen forests at an altitude above 500 asl. The associated species such as *Elaeocarpus tuberculatus, Poeciloneuron indicum, Vateria indica, Holigarna grahamii* etc. (Malakkapara) and *Dipterocarpus indicus, Elaeocarpus tuberculatus, Poeciloneuron indicum* etc. (Neriamangalam) found as top layer/ canopy species at 31-40 m height range at two study sites. At the same time, *Hydnocarpus macrocarpa* noted as sub canopy, second-third layer species at 10-28 m height range along with associated species such as small trees of *Dysoxylum malabaricum, Knema attenuata, Mesua thwaitesii. Otonephelium stipulaceum* (Malakkapara); *Mastixia arborea, Gymnacranthera farquariana, Holigarna arnottiana, Paracroton pendulus,* small trees of *Vateria indica* etc. at Neriamangalm.

The spatial distribution of *H. macrocarpa* displayed the scattered arrangement of individuals in adjacent to watercourse indicating the habitat specificity of the species. The age wise distribution in the enumerated quadrats at two sites showed below average (40%) number of pre reproductive individuals pointing towards the moderately low percent in natural regeneration ability of the species. The age profile of the populations showed that the *H. macrocarpa* individuals initiate flowering when the gbh attained around 100-110 cm along with 14-15m height range. The species diversity analysis of *H. macrocarpa* at Malakkapara (5 quadrats, each sized of 33mx33m

covering, a total enumerated area of 5445m^2) and 7 quadrats at Neriamangalam covering an enumerated area of 7623m^2 showed moderately lower dominant nature among the associates. At, Malakkapara, out of 41 species enumerated in five quadrats, *H. macrocarpa* attained with 11th position. Further, the area of occurrence of the species calculated into 12 km^2 with an area of occupancy, 0.0045km^2 covering mature individuals of 55 numbers. Similarly, at Neriamangalam, out of 81 species enumerated in 7 quadrats, *H. macrocarpa* attained with 11th position among the associates. The area of occurrence calculated into 3 km^2 with an area of occupancy of 0.012 km^2 with 150 mature individuals in the particular forest. The aggregation in area of occurrence and area of occupancy of the species in two study sites thus revealed an extent of species in 15 km^2 with 205 mature individuals under area of occupancy of 0.0165km^2. These values are falling under Critically Endangered (CR) category of IUCN wherein the extent of species is less than 100km^2 and with less than 250 mature individuals under an area of occupancy of below 10km^2.

The height wise arrangement of the species individuals (vertical profile) indicated that both stand height and girth influences the reproductive phases in each populations (Kershaw, 1973; Pascal, 1988). The dominance indicated the extreme biological competitive behavior of the species within the poor diversity of the particular quadrat, which was found favourable for species growth and reproduction. The moderately lower dominance of *D. malabarica and H. macrocarpa*, suggesting the minimum competitive behaviour due to increase in diversity and overriding importance of physical difficulties existing in respective habitats of the species.

Flushing of leaves in both the species observed along with mature leaves during February- April. In majority of forest tree

species, peak flushing noted during January –April when temperature and sunshine are maximum. Moreover, these environmental characters are regarded as suitable for maximizing photosynthesis and vegetative growth (Salisbury and Ross, 1974). The flushing along with old leaves is a characteristic of evergreen species, especially trees in order to retain leaves throughout the year for their biological functions. The extended or irregular flushing in *D. malabarica* in turn supported extended flowering and fruiting, to compensate the fruit loss as reported in *Gluta travancorica* (Jose,2001), *Mangifera indica*, *Hevea brasiliensis* (Richards,1952; Bawa and Ng,1990).

As per the various ecological studies conducted in the Western Ghats region, 26% of the tropical plants had shown the behaviour of simultaneous flushing and flowering. (Murali and Sukumar, 1994; Elourd *et al*, 1997). In *D. malabarica* and *H. macrocarpa,* flowering noted along with flushing. The Pollen-Ovule ratio (P:O) is the conservative indicator of breeding systems in flowering plants (Cruden, 1977). The flowers of *D. malabarica* produced 6,096 pollen per ovule suggesting facultative xenogamous breeding behaviour of the species as reported in *Ochreinauclea missionis,* a vulnerable tree of Western Ghats (Jose, 2001). But in the case of *H. macrocarpa* it is, 87,282 pollen per ovule and suggesting facultative nature of breeding behaviour of the species. The wilting of flowers during pollination period, undeveloped seeds in the ovary etc. in *D. malabarica* in turn reflected the pre and post fertilization anomalies taking place in the species (Bawa, 1990). The fruit infestations in forest trees are well known (Hocker, 1979). The fruit damage in *D. malabarica* is very high and this has affected the soil seed bank and seedling regeneration, which ultimately led to the rarity of the species in natural habitats. A large proportion of tropical forest trees attract vertebrate fruit

dispersers such as birds, bats etc. by producing a large number of nutritious fruits with seeds (Howe, 1984: Thornton *et al.*, 1996). In *D. malabarica*, the ripened fruits are fleshy and having pleasant odour and therefore attracted by different birds and mammals. The ripened and fallen fruits of *D. malabarica* and *H. macrocarpa* are also consumed by ground predators as the seeds contained thick endosperm.

In an ecological study, both climate and soil factors play a key role in the establishment, growth and reproduction of species (Primack, 1994). Microsite conditions such as sunlight, temperature, humidity, rainfall etc. can often control the germination and subsequent establishment of plant species. The variations in these conditions triggered the initiation and development of leafing, flowering, fruit development, dispersal, regeneration etc.

The edaphic factors such as soil moisture and temperature are important parameters in determining the survival of seedling bank. In plants, the nutrient elements are essential for various processes such as chlorophyll, protein synthesis nitrogen metabolism, lignifications etc.

The investigations on the climatic and edaphic factors of *D. malabarica* and *H. macrocarpa* in natural habitats are therefore of immense significance in understanding the niche specialities and *in situ* requirements of the species in general.

The climatic data recorded such as atmospheric temperature (day and night), atmospheric humidity (day and night) was almost identical in all the four study sites of *D. malabarica*. The soil P^H was

acidic in all the sites as reported generally for the forest soils. The soil texture varied from silt clay loam to silt sandy loam and silt loam in summer, monsoon and winter months respectively for the species. Soil temperature ranged from 20-23°C and soil moisture content recorded from 12-29% in different seasons and sites of the species. In the case of *H. macrocarpa,* the climatic data recorded such as atmospheric temperature (day and night), atmospheric humidity (day and night) was identical in the two study sites. The soil P^H was acidic in all the sites as reported generally for the forest soils. The soil texture varied from silt clay loam to silt clay and sandy clay loam in summer, monsoon and winter months respectively for the species. Soil temperature ranged from 19 -23°C and soil moisture content recorded from 15-42% in different seasons and sites of the species.

The different methods of vegetative propagation, such as rooting of stem cuttings, air layering etc. have shown difficulties in rooting success with aged plants of both *D. malabarica* and *H. macrocarpa*. However, juvenile plants of these species exhibited promising results in rooting. The juvenile stem cuttings are rooted with comparative success rate with different auxins in *D. malabarica*. A significant observation is that a moderate level of auxin concentration of NAA 3000 ppm found best rooting performance (100%), compared to lower and higher concentrations (1000 and 5000ppm). Whereas, control set resulted only with 10-15% success only. It is laso noted that the auxin was influenced the formation of more number and length of roots compared to the control set. In air layering, the auxins generally showed positive effect in rooting. A moderate level of auxin concentration such as IAA and IBA at 1000ppm and NAA at 3000ppm has resulted maximum rooting success (100%), but on increasing or decreasing the auxin concentration, the rooting ability has found

decreased. In *H. macrocarpa*, a moderately higher concentration of auxin (IBA 5000ppm) has resulted better stem rooting (66%) compared to control (30-35%). The auxin was also affected increase in number of roots compared to the control set. During air layering, moderate auxin concentration (NAA 3000ppm) has resulted maximum success (100%). By increasing or decreasing auxin level the rooting has minimized. The application of auxin may stimulate the cambial activity in juvenile cuttings at a higher rate than in adult cuttings as reported in *Terminalia chebula* by Jose and Jacob Thomas, 1998. Further, Thimann (1956) suggested that different organs respond to differently to types and range of auxin concentration, each having a promotory and inhibitory range as illustrated in *Gluta travancorica* (Jose *et al.*, 2011).

As seed propagation is the major mode of reproduction in forest trees the method, thus adopted for the large scale multiplication and conservation of both the species (Hong and Ellis, 1996: Jose and Pandurangan, 2013). In *D. malabarica*, seeds with initial moisture content of 46% lose its viability within two weeks at a critical moisture content level of 28-30%. The seeds are found sensitive and shed viability during storage in lower temperature due to the intermediate seed type behaviour. Therefore, seeds are recommended for storage in closed polybags/poly carbonate bottles in room conditions for moderate period in extending viability as reported in *Swietenia mahagoni* and *Xanthoxylum rhetsa* (Kindt *et al.*, 1997, CABI, 1998).

The *H. macrocarpa* seeds are recalcitrant and therefore found sensitive towards desiccation and chilling storage conditions. Seeds with initial moisture content of 45% lose its viability within one week at a critical moisture content level of 16-17%. However, seeds enabled

for storage more than two months in the closed poly carbonate bottles, kept at seed bank conditions maintained at 20°C and 40% RH as reported in different forest tree species (Anilkumar *et al.*, 1996; 2002).

In *D. malabarica*, out of four *in situ* areas where seedling planting done, 75-80% seedling survival along with 4-7 cm height increment has been recorded within 1.5 years of planting. The success rate thus indicating the ability and growing preference of seedlings to naturalize in its original habitats. Similarly out of 6 *in situ* areas where seedling planting done for *H. macrocarpa,* 40-70% seedling survival along with 3-23 cm height increment has noticed within 1.5 years of seedling planting. The seedlings planted *in situ* have often experienced with climatic variations mainly of poor rain fall, wildlife interventions, insect–pest incidences etc. which has been adversely affected the seedling survival and their growth (Jose *et al.*, 2001; 2011; Pandurangan, 2003; Swarupanandan *et al,* 2013). But the seedling survival in *ex situ* conditions are fairly better for both the species and noted @ 70-98% along with 3-6 cm height increment for *D. malabarica* and 80-94% along with 4-30 cm height increment within 1.5 years of seedling planting.

Thus the present study is concluded that after exploring the species distribution/ population status, ecosystem features including climatic and edaphic factors, life history traits, development of vegetative and seed propagation/multiplication strategies, seed storage practices followed by restoration are invariably amenable for the rescue and recovery of these endangered species and ensured the conservation and management of existing populations subsequent resource based sustainable utilization in the long run.

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