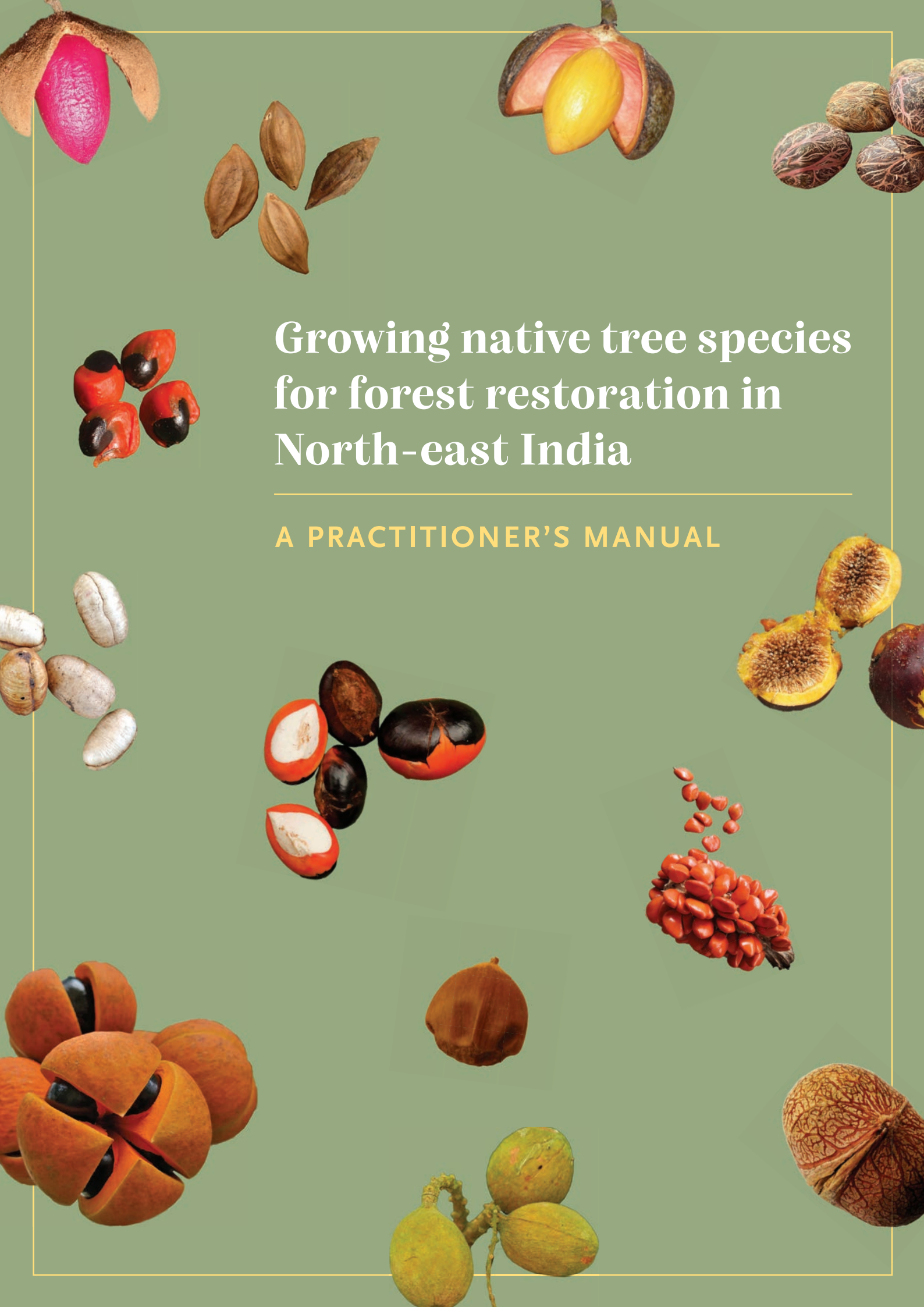

Growing native tree species for forest restoration in North-east India

A PRACTITIONER'S MANUAL

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Contents

Introduction

Globally, tropical forest loss and degradation are proceeding at an alarming rate, almost twice the rate of forest gain. There is increasing recognition of the critical role these ecosystems play in our planet's health and well-being. By focusing on ecosystem and habitat restoration efforts, we can mitigate the negative impacts of past losses and create a more sustainable future for our forests and the communities that depend on them.

India's State of Forest Report 2021 states that the states of North-east India have lost 1020 km^2 of forests between 2019 and 2021. According to Global Forest Watch, the top 5 regions with 60% of all tree cover loss between 2001 and 2023 in India are all from North-east India. North-east India, while facing significant challenges associated with forest loss, also presents significant opportunities for forest restoration.

By restoring degraded patches within these biodiversity-rich forests, we can help reduce habitat fragmentation and support the recovery of wildlife, including iconic species like tigers and elephants.

Restoring forests also offers numerous benefits beyond wildlife conservation. It promotes carbon sequestration, helping to combat climate change. It provides essential ecological services like clean air and water, improving human health and well-being. It also aligns with India's ambitious commitments under the Bonn Challenge, which aims to restore 21 million hectares of degraded forests by 2030 and the Global Forest Goals under the United Nations Strategic Plan for Forests (2017-2030).

In November 2021, the Arunachal Pradesh State Government adopted the Pakke Tiger Reserve 2047

Declaration on Climate Change Resilient and Responsive Arunachal Pradesh. The Declaration directly references the restoration of degraded forests as a means of building Arunachal Pradesh's resilience to climate change. The Arunachal Pradesh Forest Department will play a key role in implementing these initiatives throughout the state.

One of the key priorities is setting up nurseries for forest rehabilitation. However, there is a dearth of forest nurseries where a diversity of appropriate ecologically important native tree species are grown in most of North-east India. While there are numerous government and private nurseries, most grow only a few native species along with some non-native or economically important tree species from other parts of India. They also have cultivated varieties of some fruit species.

The availability of a diversity of native species is essential for carrying out ecologically meaningful restoration. A plant nursery is a critical need in any restoration programme. Such plant nurseries also need to be established relatively close to sites where restoration will be done as it can be harmful to plant even similar species sourced from far away areas, as there are likely to be differences between different populations of the same species. Seed collection, nursery development and maintenance are year-round activities as the plants require continuous nurturing and because seeds of different trees become available at different times within a year. It is important to know and understand the species composition of an area and the periods when different species fruit to ensure that seeds of a diversity of species can be collected.

This practitioners' manual attempts to bring together some knowledge and experience based on the raising and growing of a variety of native tree species from Pakke's tropical semi-evergreen and evergreen forests (north bank of the Brahmaputra) in a native forest species nursery established in 2014

in Seijosa, Arunachal Pradesh. We have provided some basic nursery management tips. To keep this manual at a reasonable size and easy to use, we selected 38 tree species for which we have provided more detailed information on ecology, seed dispersal mode, basic fruit/flower characters, flowering and fruiting periods (based on our long-term studies) using Page et al. (2022) as a reference. We have provided the germination methods that we followed. For these species, we have provided images of fruits/seeds/flowers/habit and of the saplings.

For all other species that were raised in our nursery, we have provided a table with the scientific and local names and the fruiting periods so that practitioners who want to grow them know when to look for and source seeds. We have also provided a table with the survival percentage of some tree species in restoration sites in Pakke. Some basic guidelines on restoration principles and practice and information on alien species in north-east India are also included. Much of this is adapted and modified from Mudappa & Raman (2020).

Nursery Management Tips

Seed collection and sowing
Collect from several different locations, not more than 50 seeds from below one tree. Soak collected seeds/fruits overnight, some seeds may require soaking for 3-4 days (such as Nahar, Dhuna, Lepchipoma, Rudraksh). Seeds are placed approximately 2 inches apart when sowing and sown in a single line in a seed bed. Some seeds like Kalakari (*Picrasma javanica*), and other similar smaller seeds can just be cast onto the prepared seedbed and then later covered with soil. Seed beds are watered with water cans every day until the seedlings are transplanted into polybags.

Transplanting
Before transplanting, prepare polybags by filling in soil. Germinated seedlings are then transplanted. Rescued seedlings (wildings) can be directly planted in the polybag.

Potting mixture
It is made by composting fallen and dry leaves. Make a pit, put dry leaves etc. Leave them in the pit for 6 months for it to compost. Composted soil can be extracted from below the compost pile.

Polybag size
The size we use in our nursery is 10 X 8 inches. These are for saplings that we have grown to a height of about 50-60 cm. Size of 12 X 4 inches (box type) is used and recommended by NCF's Western Ghats restoration team. However, smaller sizes may be more suitable and feasible where saplings need to be carried some distance in hilly terrain.

Light and water requirement
The polybags are kept under shade-net after transplanting. The number of days for which saplings are placed under the shade-net varies based on the species. They are watered every day. Once the saplings have grown to above 30-40 cm in height, watering can be done every alternate day in the dry season.

Weeding
Under the shade-net, the polybags are weeded as and when required.

Maintenance
The polybags with the saplings are moved at regular intervals to avoid penetration of the roots through the polybags into the soil. If the roots grow out of the polybags, they are trimmed regularly (depending on the species) at the right time of the day. In the dry season, it is done during the early morning or evening hours followed by watering. In the summers, the trimming is done every 2 months and in the winters, since growth is slower, the roots are trimmed after 3-4 months. The polybags also must be weeded at regular intervals.

Hardening of saplings
Before the planting season, the saplings are hardened by watering them less frequently (3-4 days gap) to prepare them for the external environment before they are transplanted to the field. This process helps saplings build resilience to withstand environmental stressors such as fluctuations in temperature, wind, direct sunlight, and lower humidity, which they are likely to face once they are planted out in the open in the wild.

Species that we could not germinate/raise in our nursery
There are several ecologically important species that we failed to germinate in our nursery using

the standard germination methods that worked for most species. We have listed some of these below. For some of these species, the manuals by SFRI, Itanagar contain details of more elaborate germination methods that may be needed.

Stereospermum tetragonum (Paroli): Seeds were sown directly into seedbeds, but germination was very low.

Pterospermum acerifolium (Hatipaila): Most of the time, the available fruits or seeds collected from under the fruiting trees are damaged or infested, therefore, finding viable good seeds for planting is difficult.

Baccaurea ramiflora (Kusumtenga): Seeds were sown directly into the seedbeds, but germination was low.

Dalyrympelea pomifera (Pani amora): Germination was low through seeds but it was successful through seeds found in the civet scats.

Cinnamomum bejolghota (Jungli tezpat): Fruits or seeds collected from under the fruiting trees are usually damaged or infested, therefore, finding viable good seeds for planting is difficult.

Cinnamomum glaucescens (Gonsorai): Fruits or seeds collected from under the fruiting trees are damaged or infested, therefore, finding viable good seeds for planting is difficult.

Certain species like *Duabanga grandiflora* (Khokun) and *Tetrameles nudiflora* (Bhelu) were grown in the nursery only from rescued seedlings (wildlings). In the case of *Tetrameles nudiflora*, interestingly we also had seedlings coming up in our polybags on their own! The small seeds are likely to have been carried by the wind. For *Duabanga*, the SFRI manual (see page 109) has provided germination protocols to grow the species in the nursery.

Actinodaphne obovata

Assamese: *Pati-khunda, Noga-bagnola, Paji huta, Petarichowa*
Idu Mishmi: *Lohodim-bõ, Aehodim-bõ*
Nepali: *Runchepat*
Nyishi: *Rasii*

This evergreen tree species is relatively common in low to mid-elevation forests. This species is dioecious which means there are separate male and female trees. It is found throughout North-east India.

Flowering: January to May, with peak from February to March, ***flowers*** up to 0.5 cm (male and female flowers), yellow and present in clusters at the axil.

Fruiting: April to November with ripe fruit availability peaking in August-September, ***fruits*** 1.5 cm long, 2 cm broad, fleshy, present in a bunch; green, yellow and red when unripe, black when ripe, one seeded.

Dispersal mode: Birds (hornbills, bulbuls, barbets) and macaques. Also hoarded by terrestrial rodents.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 15 days; 4 to 24 days. Usually 1-2 weeks in the dry season, 3-4 days in the rainy season.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7 days; under shade-net for 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Ailanthus integrifolia

Synonym: *Ailanthus grandis*
Assamese: *Borpat*
Idu Mishmi: *Amombõ, Awunyi-bõ*
Nepali: *Gokul*

This deciduous tree has a long straight cylindrical bole with no buttresses and grows up to 45 m tall. This emergent species is also used for nesting by hornbills. It is found throughout the North-east and peninsular India.

Flowering: September to October, ***flowers*** 0.4-0.6 cm long, green, present in clusters at the end of branch.

Fruiting: October to April with peak fruit availability from November to December, ***fruits*** oblong, 10 cm long, 3.5 cm broad, flat; green when unripe, brown when ripe, one seeded; seed flat.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: Overnight soaking in cool water, removing pulp and sowing.

Sowing method: Seedbeds.

Germination time: Average 28 days; 14 to 38 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-14 days; under shade-net for 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Balakata baccata

Mouse Deer's Rubber Tree

Assamese: *Selleng, Mota Selleng, Lewa*
Bengali: *Chota-mal*
Garo: *Sam-sim*
Khasi: *Dieng-ja-lonh-ehr*
Mizo: *Thing-vawk-pui;*
Nepali: *Ankhataruwa*

This evergreen species grows in primary and secondary forests, near streams, in elevations up to 1000 m. Trees are up to 12 m tall. It is found in the Andaman and Nicobar Islands and throughout North-east India.

Flowering: May, ***flowers*** yellow, appear in clusters at the branch tip.

Fruiting: July to September, ***fruits*** nearly spherical, 0.8-1.2 cm diameter, fleshy; green when unripe, purple, brown or red when ripe, two seeded; seeds hard, globose.

Dispersal mode: Birds (bulbuls, green pigeons), also possibly civets.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 28 days; often within 10-15 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-14 days; under shade-net for 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Beilschmiedia assamica

Assamese: *Amchoi, Kanthal patia*
Idu Mishmi: *Toorumbõ, Sidikhim-bõ*
Nepali: *Tarsing*

The evergreen species is seen in lower elevation forests with trees up to 20 m tall. The ripe black fruits are an important food resource for hornbills in winter. It is found in Arunachal Pradesh, Assam, and Sikkim.

Flowering: March to May, ***flowers*** up to 0.5, yellow, in clusters.

Fruiting: October, ***fruits*** rounded, 2.5-5 cm long, 1.2-2 cm broad, fleshy; green when unripe, black when ripe, one seeded; seed hard.

Dispersal mode: Birds (mainly hornbills), macaques and squirrels.

Germination Methods

Pre-sowing treatment: Overnight soaking in cool water, removing pulp and sowing.

Sowing method: Seedbeds.

Germination time: Average 61 days; 17 to 93 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybag after 14 days, under shade-net: 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Bombax ceiba

Red Silk Cotton Tree

Synonym: *Bombax malabaricum*
Assamese: *Semal*
Bodo: *Simla*
Idu Mishmi: *Edhumbõ*
Nyishi: *Sangdo, Sod*

This deciduous tree with spreading canopy and horizontal branching is found on river banks and floodplains up to 1400 m. It grows up to 40 m tall. The flowers are pollinated by many insects, bees, birds and squirrels. The tree is used as a roost and nest tree by birds. The seeds are eaten by tree squirrels. It is found throughout North-east India and peninsular India.

Flowering: January to March, ***flowers*** 5-15 cm, showy red.

Fruiting: March to May, ***fruits*** long, elongated, 10-15 cm long, dehiscent, dry; green when unripe, brown when ripe, many seeded; seeds embedded in thick white woolly fibres, black.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 31 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7 days; rescued wildlings and trans-planted saplings stay under shade-net for 1-1.5 months; later kept outside, until ready for planting in 1-1.5 years.

Canarium resiniferum

Assamese: *Dhuna, Lal dhuna*
Nyishi: *Sanglum*

This species is evergreen and grows up to 40 m tall, with separate male and female trees. They are more common and seen in slightly drier lowland habitats than *C. strictum* (Kaladhuna). The seeds are preyed on by terrestrial rodents. It is found in Arunachal Pradesh, Assam, Meghalaya, and Nagaland.

Flowering: May to June, ***flowers*** small, white, in clusters at branch axil.

Fruiting: August to March, peak ripe fruit availability is from November to December, ***fruits*** elliptic, 5 cm long, 2 cm broad, fleshy, rough; green when unripe, yellow when ripe, one seeded; brown when ripe, angular.

Dispersal mode: Mammals (barking deer and sambar).

Germination Methods

Pre-sowing treatment: Soak fruits for 15-20 days in cool water, followed by de-pulping and sowing.

Sowing method: Seedbeds.

Germination time: Average 56 days; 14 to 102 days; 1-2 weeks (rains), 3-4 months (dry).

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-8 days; under shade-net: 2-2.5 months; later kept outside until ready for planting in 1-1.5 years.

Castanopsis indica

Indian Chesnut

Synonym: *Quercus indica*
Apatani: *Kwra*
Assamese: *Hingori*
Idu Mishmi: *Aekambõ*
Nepali: *Musuri katus*
Nyishi: *Kora rakhin*
Yobin: *Chi-chye, Katus*

This evergreen species occurs from low elevations up to 1500 m and is up to 20 m tall. This species is used as a nesting tree by flying squirrels in Arunachal. It is found in Arunachal Pradesh, Assam, Meghalaya, Nagaland, and Sikkim.

Flowering: March to May, ***flowers*** white, male flowers in clusters, female flowers usually solitary.

Fruiting: The fruits take a long time to mature and dehisce only the following year from September to November, ***fruits*** roundish, nut, 1.25 cm long, 1 cm broad, densely hairy, spiny; green when unripe, brown when ripe, 1-3 seeded; seeds with depression at the top.

Dispersal mode: Mechanically-dispersed (gravity), seeds are consumed by squirrels and terrestrial rodents who may act as secondary seed dispersers.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 60 days; 30-88 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1-3 months; later kept outside, until ready for planting in 1-1.5 years.

Chisocheton cumingianus

Synonym: *Chisocheton paniculatus*
Assamese: *Banderdima*
Idu Mishmi: *Ibrisum-bõ*
Nyishi: *Poyo nyikfe, Tosu sen*

This evergreen tree is among the most common trees in the low-elevation forests in Assam and Arunachal and is up to 15 m tall. It occurs up to an elevation of 1300 m. It is found in Arunachal Pradesh, Assam, Meghalaya, Tripura, northern West Bengal.

Flowering: May to July, ***flowers*** 2-3 cm long, white, in drooping clusters from axil.

Fruiting: March to July, with the ripe fruiting peak in April-May, ***fruits*** spherical, 6.5-8cm in diameter, smooth, breaking in 4 parts; light yellow when unripe, pinkish-red when ripe, 4 seeded; seeds glossy, black or chestnut-coloured, partly covered on top by a fleshy orange-white arillode.

Dispersal mode: Birds (mainly hornbills, imperial pigeons).

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 33 days; 17-61 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 3 months; later kept outside, until ready for planting in 1-1.5 years.

Choerospondias axillaris

Nepali Hog Plum

Synonym: *Spondias axillaris*
Apatani: *Sanko Ayi*
Assamese: *Lepchipoma*
Nepali: *Lapsi*
Nyishi: *Balam*

This deciduous species is usually up to 30 m tall, with separate male and female trees. The fruits are edible and eaten by local people. In Nepal, this species is cultivated and its fruits are made into pickles and candied sweets. It is found in Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim, and northern West Bengal.

Flowering: February to May, ***flowers*** 0.3-0.6 cm, female flowers in clusters from axil, male flowers solitary, white.

Fruiting: July to October with peak from August to September in western Arunachal. In higher elevations in eastern Arunachal, ripe fruits are seen from November to January, ***fruits*** oval-shaped, 3.5 cm long, 2.5 cm broad, green when unripe, yellow when ripe, one seeded; seeds oval, hard.

Dispersal mode: Mammals (barking deer, sambar).

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 42 days; 13 to 93 days; 1-2 months (rains), 6-12 months (dry).

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1-1.5 months; later kept outside, until ready for planting in 1-1.5 years.

Cryptocarya amygdalina

Synonym: *Cryptocarya floribunda*
Assamese: *Bonsum*

The species is quite common in more hilly areas and ranges from 300 m to 1350 m. The trees are evergreen up to 25 m tall. The seeds are primarily bird-dispersed. It is found in Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim.

Flowering: February to April, ***flowers*** 0.2-0.5 cm across, white, in clusters.

Fruiting: July-August, ***fruits*** elongated, 2-2.5 cm long, 0.8-1 cm broad, fleshy, tapering at both ends; green when unripe, black when ripe, one elongated seed.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 1-2 weeeks.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 1-1.5 months; later kept outside, until ready for planting in 1-2 years.

Dillenia indica

Elephant Apple

Adi: *Champak, Sumpa*
Assamese: *Outenga*
Bengali: *Chalta*
Idu Mishmi: *Chopambõ*
Nepali: *Pachpale*
Nyishi: *Jampa, Sompa, Bauu*
Yobin: *Masansi*

This species with distinctive reddish bark is common in the low-elevation forests, often found along perennial streams. The large fragrant white flowers are pollinated by beetles and smaller insects. It is found in Andaman Islands (introduced), throughout North-east India, peninsular India, and northern West Bengal.

Flowering: April to July, ***flowers*** 10-25 cm across, solitary, in the branch tip, white;

Fruiting: November to April peaking in January, ***fruits*** 10-12 cm in diameter, round, pulpy, smooth; green when unripe, yellow when ripe; seeds many, embedded in the pulp, kidney-shaped, hairy outside.

Dispersal mode: Elephants, sometimes also by water.
Fallen fruits are accessible for consumption by macaques, rats and squirrels.

Germination Methods

Pre-sowing treatment: No germination success from direct sowing of seeds. Seeds were collected from elephant dung—seeds separated and cleaned from the dung and sown without any treatment.
Sowing method: Seedbeds.

Germination time: Average 24 days; 10 to 35 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7 days; under shade-net: 2-2.5 months; later kept outside, until ready for planting in 1-1.5 years.

Dysoxylum cauliflorum

Synonym: *Dysoxylum angustifolium*
Assamese: *Goborkhutla*

This evergreen species, which can grow up to 30 m tall, is found up to 1500 m. The tree is cauliflorous, producing flowers and fruits on the stems and branches. It is found in Arunachal Pradesh, Assam, and Meghalaya.

Flowering: March to June, ***flowers*** 0.7-1 cm long, in clusters along the tree trunk, white.

Fruiting: April to May and October, ***fruits*** partly globose, 3-4 cm long, smooth; red when unripe, brown when ripe, two to three seeded; seeds rufous to dark brown, covered by red, fleshy aril.

Dispersal mode: Hornbills and other birds.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 35-36 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybag after 7-14 days; under shade-net: 2.5-3 months; later kept outside, until ready for planting in 1-1.5 years.

Dysoxylum gotadhora

Cup-Calyx White Cedar

Synonym: *Dysoxylum binectariferum*
Assamese: *Banderdima*
Bengali: *Borogotadhora*
Idu Mishmi: *Ibrisum-bõ*
Nyishi: *Poyo nyikfe, Tosu sen*

This mid-canopy evergreen tree is seen in the lower elevations of Arunachal and Assam, and is up to 20 m tall. This tree is heavily infested by a caterpillar of a moth and the leaves are heavily defoliated, while saplings are also affected by herbivory. It is found throughout North-east India and peninsular India.

Flowering: June to July but can be staggered up to August-September, ***flowers*** 0.9-1 cm long, in clusters from axil, white.

Fruiting: February to May with peak ripe fruit availability in March-April with unripe fruits seen almost throughout the year, ***fruits*** rounded, 5.5-6 cm diameter, smooth, dehiscing in 4 part; pale yellow when unripe, deep orange when ripe, four seeded; seeds green, heart-shaped, covered with black aril.

Dispersal mode: Hornbills and imperial-pigeons.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 24 days; 13 to 76 days.
Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 2-2.5 months, later kept outside, until ready for planting in 1-1.5 years

Dysoxylum procerum

New name: *Prasoxylon excelsum*

Synonym: *Dysoxylum excelsum*
Assamese: *Amselleng, Lali*
Idu Mishmi: *Sepa-bõ*
Nyishi: *Siihiilalup*

This evergreen species is found in undisturbed forests up to 1100 m and is up to 15 m tall. It is found in the Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Meghalaya.

Flowering: Mainly from June to January (with a peak in November-December) but has extended and erratic flowering with flowers seen in all the months of the year, ***flowers*** up to 1.25 cm long, in clusters from axil, white.

Fruiting: November to April, with peak ripe fruits in March-April, ***fruits*** spherical, 4 cm in diameter, smooth; red when ripe, in clusters; 2-3 seeded; seeds brownish with wavy lines, covered with red, fleshy aril.

Dispersal mode: Hornbills and imperial-pigeons.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 34 days; 15-85 days.

Time needed for sapling to be ready for planting (50-60 cm): transplanted to polybags after 20 days approx; under shade-net: 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Endospermum chinense

Assamese: *Phulgamari*
Idu Mishmi: *Sopum-bõ*

This evergreen species is seen in lowland forests near streams at elevations below 800 m and can grow up to 35 m tall, with separate male and female trees. The leaves are heavily defoliated by the larvae of a moth belonging to genus *Asota*. It is found throughout North-east India.

Flowering: May to August, ***flowers*** 0.2-0.6 cm long, in clusters from axil, male and female flowers different.

Fruiting: August to November, ***fruits*** nearly rounded, 1 cm diameter, fleshy, hairy; green when unripe, yellow when ripe, 3 seeded; seeds ellipsoid, black.

Dispersal mode: Likely by birds.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 17 days; 10-30 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7 days; under shade-net: 2-2.5 months; later kept outside, until ready for planting in 1-1.5 years.

Ficus drupacea

Brown-Woolly Fig, Mysore Fig

Synonym: *Ficus mysorensis*

This evergreen species grows in montane forests along streams from sea level to 1500 m growing up to 25 m tall. It is found throughout North-east India and peninsular India.

Fruiting: January and April. In Pakke, it has been recorded fruiting throughout the year, but mainly between February to September and November, ***figs*** ellipsoid, 1.5-2.5 cm long, 1-2 cm broad, in clusters of two from axil, short stalked; greenish or yellow when unripe, reddish-orange or red when ripe.

Dispersal mode: Birds (hornbills, green pigeons, mynas) and mammals (macaques, civets).

Germination Methods

Pre-sowing treatment: No germination success from direct sowing of seeds or stem cuttings. Grown from seeds found in hornbill and rhesus macaque droppings, the collected faeces is spread directly on the motherbeds and covered with a thin layer of soil.

Sowing method: Seedbeds.

Germination time: 38 days (from macaque dung).

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 2-3 months, shade-net: 2 months, kept outside, until ready for planting in 1-1.5 years.

Ficus nervosa

Assamese: *Chepani-dimoru, Khanpati dimoru, Kharipati dimoru*
Idu Mishmi: *Areymbõ, Mapam-bõ*
Karbi: *Thebu*
Nyishi: *Toku Kuto*

This species is found in deciduous, semi-evergreen and evergreen forests up to 1600 m and are up to 30 m tall. It is found in Andaman and Nicobar Islands, throughout North-east India and peninsular India.

Fruiting: Throughout the year, highest from July to September, ***figs*** 1-1.2 cm diameter, in solitary or in pairs from axil, stalk 0.7-1.3 cm long, green and tuberculated when unripe, red-yellow and smooth when ripe.

Dispersal mode: Birds (barbets, green-pigeons and Asian fairy-bluebirds) and mammals (civets and wild pigs).

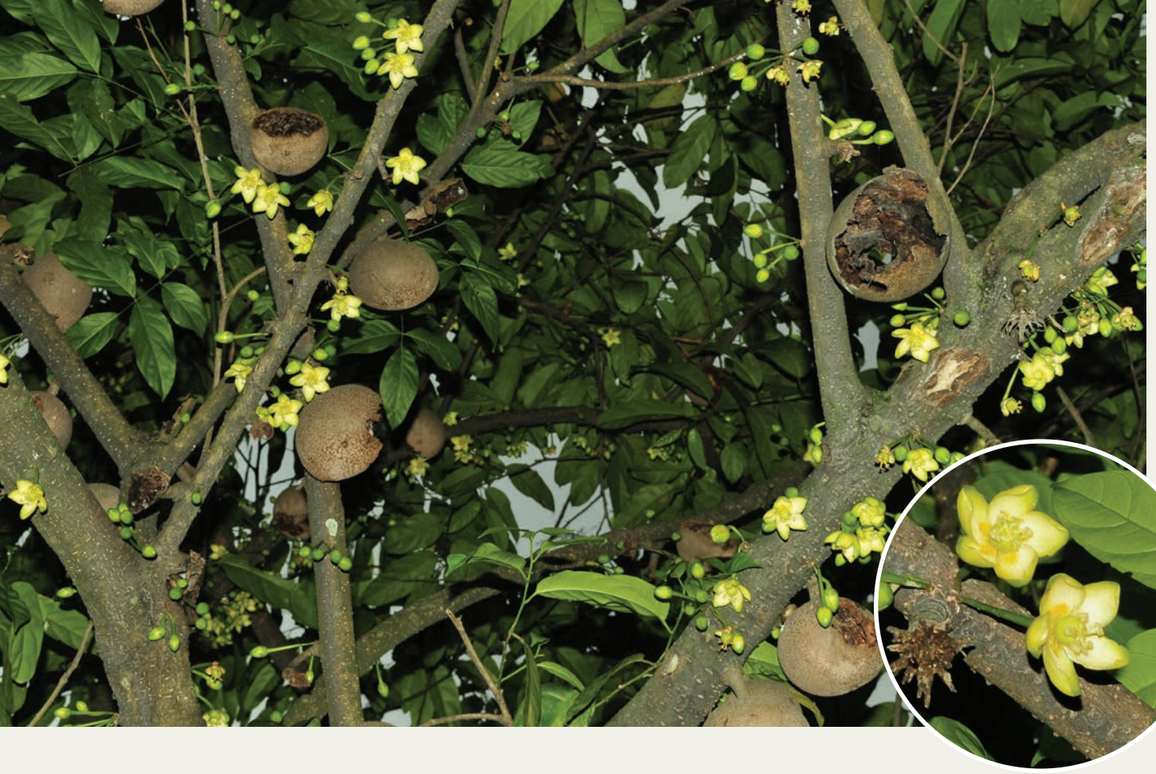
Germination Methods

Pre-sowing treatment: No germination success from direct sowing of seeds or stem cuttings. Grown from seeds found in hornbill, wild pig and civet droppings, the collected faeces is spread directly on the motherbeds and covered with a thin layer of soil.

Sowing method: Seedbeds.

Germination time: 97 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 1.5 to 2 months, until the saplings sprout 3-4 leaves; under shadenet: 2.5-3 months; kept outside until ready for planting in 1-1.5 years.



Gynocardia odorata

Assamese: *Chalmugra, Bonsha, Lemtem*
Bengali: *Chaulmugra*
Garo: *Sikelupi*
Idu Mishmi: *Ikhumbõ*
Nepali: *Gandare, Koitur*
Nyishi: *Tekh sen*

This evergreen species occurs in evergreen wet forests from 300 m to 1200 m elevations and can grow up to 20 m tall with separate male and female trees. It is found throughout North-east India.

Flowering: March to May, ***flowers*** 3-4 cm across, female flowers bigger than male flowers, showy, fragrant, yellow, along the main trunk.

Fruiting: November to January, ***fruits*** rounded, 7-12 cm in diameter, borne on trunk and branches, rough textured; brown when ripe, many seeded; seeds obovoid to oblong, embedded in pulp.

Dispersal mode: Mammals (macaques, civets).

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 28 days; 15 to 52 days.

Time needed for sapling to be ready for planting (50-60 cm): 10-15 days; transplanted to polybags after 7 days; under shade-net: 1-2 months; later kept outside, until ready for planting in 1-1.5 years.

Horsfieldia kingii

Synonym: *Myristica kingii*
Assamese: *Ramtamul*
Bengali: *Ramsupari*
Nepali: *Ramgua*
Nyishi: *Mouru sangphu*

This evergreen tree grows up to 20 m tall, with branches usually crowded on top of the trunk and somewhat horizontal. It is relatively rare with a patchy distribution with separate male and female trees. The species does not fruit every year. It is found in Arunachal Pradesh, Assam, Meghalaya, Sikkim, Tripura.

Flowering: April to July, ***flowers*** 0.3-0.5 cm across, yellow, in clusters from axil.

Fruiting: February to May with a peak from February to March, ***fruits*** ovoid or ellipsoid, 4-4.5 cm long, 2.5 cm broad, leathery; green when unripe, brown when ripe, one seeded; seeds cream-coloured, elongated ovoid, covered with bright yellow aril. The fruits dehisce at maturity.

Dispersal mode: Hornbills and imperial-pigeons, seeds heavily preyed on by rodents

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 40 days; 10 to 74 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 2-2.5 months; later kept outside, until ready for planting in 1-1.5 years.

Litsea monopetala

Synonym: *Litsea polyantha*
Assamese: *Muga, Sualu, Khuwalu, Bon-khuwalu*
Bengali: *Bara kukurchita*
Nepali: *Kutmira, Katamero*

The species grows in mixed lowland and montane semi-evergreen and evergreen forests at elevations up to 1,500 m and can grow up to 20 m tall with separate male and female trees. It is found in Andaman and Nicobar Islands, throughout North-east India and peninsular India.

Flowering: March to May, flowers 0.5-1 cm across, in groups of 5-6 flowers, yellow, in cluster from axil, enclosed together by bracts.

Fruiting: June to August, fruits partly rounded, slightly elongated, 0.7 cm long, 0.6 cm broad, fleshy, stalked; green when unripe, shiny purple-black when ripe one seeded.

Dispersal mode: Birds.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 21 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7 days; under shade-net: 1-2 months; later kept outside, until ready for planting in around 1.5 years.

Litsea panamanja

Synonym: *Tetranthera panamanja*
Idu Mishmi: *Athrembõ, Aetam-bõ, Ambom-bõ*

This evergreen species occurs in evergreen broad-leaved forests from 200 m to 2000 m and grows up to 25 m tall with separate male and female trees. It is found in Arunachal Pradesh, Assam, Meghalaya, Nicobar Islands, Sikkim, and northern West Bengal.

Flowering: March to April, ***flowers*** 0.5-0.6 cm across, in clusters from axil, white.

Fruiting: May to August with peak ripe fruits from July to August, ***fruits*** rounded, 1.5 cm long, 1.8 cm broad, fleshy, thickened stalk; green when unripe, black when ripe, one seeded; seed stony.

Dispersal mode: Hornbills and other birds, secondarily dispersed and cached by rodents and *Brachytrupes* sp., a cricket species.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 15 days; 4 to 32 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1.5 approx months; later kept outside, until ready for planting in 1-1.5 years.

Livistona jenkinsiana

Major Jenkins' Fan Palm, Assam Fan Palm

Assamese: *Tokko, Toko pat*
Idu Mishmi: *Sarambõ*
Nyishi: *Tah, Tahii*

This economically important evergreen palm tree is common on moist hilly slopes. With an annulate trunk, this tree grows up to 15 m tall. It is also found in Arunachal Pradesh, Assam, Meghalaya, Nagaland.

Flowering: February to March, ***flowers*** 0.1-0.4 cm long, in closed clusters with boat-like structure, covered with spathe, greenish or yellow.

Fruiting: September to February, with peak ripe fruiting from October to November, does not fruit every year, ***fruits*** rounded, slightly tapered below, smooth; green when unripe, leaden dark blue or bluish purple when ripe, one-seeded; seed stony.

Dispersal mode: Birds (hornbills, great barbets, cuckoo-doves, imperial-pigeons) and mammals (deer, bears and macaques), fallen fruits and seeds are eaten by terrestrial rodents and wild pigs.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly in polybags.

Sowing method: Pot/polybag directly.

Germination time: Average 15 days; 4 to 32 days. Takes more than 6 months in the dry season.

Time needed for sapling to be ready for planting (50-60 cm): 6 months, under shade-net: 2-4 months; later kept outside, until ready for planting in 2.5-3 years.

Magnolia hodgsonii

Hodgson Magnolia

Synonym: *Talauma hodgsonii*
Adi: *Burgang-asing*
Apatani: *Jilying*
Assamese: *Boromthuri*
Khasi: *Dieng-soh-pydem*
Nyishi: *Parampare*

This species is commonly seen below 300 m, though elevational range is reported as 800 m to 1500 m. This is an evergreen species and grows up to 15 m tall. It is insect-pollinated. It is found in Himachal Pradesh, throughout North-east India, and West Bengal.

Flowering: Mainly in May but some flowering seen from March to November, ***flowers*** 7-10 cm across, solitary at tip of the branch, fragrant, mostly white, reddish in the outer side of the outer whorl.

Fruiting: May to November with ripe fruits mainly in October–November, ***fruits*** 8-10 cm long, 6-7 cm broad, ellipsoid, formed by aggregation of 40-80 follicles; whitish in colour; seeds black, covered with red aril.

Dispersal mode: Birds (niltavas, barbets, cochoas, mynas). The seeds are also eaten by tree squirrels, while fallen seeds are consumed by terrestrial rodents and pheasants.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 53 days; 9 to 98 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 2-2.5 months; later kept outside, until ready for planting in 1-1.5 years.

Micromelum integerrimum

Entire-Leaf Lime Berry

Synonym: *Micromelum pubescens*
Nyishi: *Sutum tanyi*

This is a very common evergreen understorey species in the low elevation forests up to 1200 m and grows up to 6 m tall. It is found in Andaman Islands, and throughout North-east India.

Flowering: February to April, ***flowers*** 0.5-1.5 cm across, in clusters at the branch tip, fragrant; white.

Fruiting: July to September, ***fruits*** oblong or ellipsoid, 1 cm long, 0.6 cm broad, dry; green when unripe, orange when ripe, one seeded; seeds oblong.

Dispersal mode: Small birds (fairy-bluebirds, barbets, bulbuls and leafbirds).

Germination Methods

Pre-sowing treatment: Sowing the fruits directly as the seeds are very small.

Sowing method: Seedbeds.

Germination time: Average 16 days; 3 to 44 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 1-2 months; later kept outside, until ready for planting in 1-1.5 years.

Monoon simiarum

Synonym: *Polyalthia simiarum*
Assamese: *Kari, Boga khamtoi, Boga koliori*
Bodo: *Silem-phang*
Garo:*Bolang-banchibok, Jiri, Borsthi*
Khasi: *Dieng-ja-roi*
Kuki: *Jethou*
Mising: *Mikir asing*

This evergreen species is common in lower elevation forests and is seen up to 1000 m. It grows up to 20 m, has a straight bole with thin horizontal branches. The flowers are pollinated by insects. It is found in Andaman Islands, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Orissa, Sikkim, West Bengal.

Flowering: February to October, ***flowers*** 2-5 cm across, clustered in axils of leaves or on old branches, green-yellow.

Fruiting: Main peak is from May to July, and a minor one from December to February with ripe fruits available for almost nine months of the year, ***fruits*** in cluster, each 3 cm long, 1.75 cm broad, gradually narrowed to a stalk 3-4 cm long; green and orange-red when unripe, blue-black when ripe; seed one per fruitlet, ovoid grooved.

Dispersal mode: Birds (hornbills and green pigeons) and mammals (macaques, bats and civets).

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Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 20 days; 11 to 51 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-8 days; under shade-net: 2-2.5 months; later kept outside, until ready for planting in 1-1.5 years.

Oroxylum indicum

Tree of Damocles, Indian Trumpet Flower, Broken Bones

Assamese: *Totola, Toguna*
Bengali: *Shona*
Hindi: *Bhut vriksha*
Idu Mishmi: *Arwu kawu-bõ*
Mizo: *Archangkawm*
Nyishi: *Laata*
Tangkhul Naga: *Phong*

This is a common deciduous tree often seen in open areas and degraded land and grows up to 12 m tall. The large white flowers bloom at night and are bat-pollinated. The sword-like fruits hang from the tree when it is leafless. It is found throughout North-east India and peninsular India.

Flowering: June to July, ***flowers*** showy, 2-6 cm long, in clusters at the branch tip, sometimes reddish-purplish or pinkish-yellowish white.

Fruiting: October to December, ***fruits*** 50-62 cm long, 4-9 cm broad, sword-like, dry dehiscent; green when unripe, brown when ripe, many seeded; seeds flat, papery, winged.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: Sowing directly.

Sowing method: Seedbeds.

Germination time: Average 16 days; 6 to 28 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 8-10 days; under shade-net: 1-2 months; later kept outside, until ready for planting in 1-1.5 years.

Phoebe cooperiana

Adi: *Tapir, Tapil*
Apatani: *Samper*
Assamese: *Mekahi*
Galo: *Hisir*
Idu Mishmi: *Educhi, Indimbõ*
Nyishi: *Sanchar, Sangcher*
Yobin: *Sifile*

This evergreen tree has a clean straight bole and compact crown with separate male and female trees. It can grow up to 30 m tall and occurs from 150 m to 1600 m elevation. It is very rare in most parts of Arunachal Pradesh because of harvest for timber. The edible fruits are harvested for consumption in Arunachal. It is found in Arunachal Pradesh and Assam.

Flowering: March to April, ***flowers*** 0.6-1 cm long, in clusters from axil, white.

Fruiting: June to August, ***fruits*** ellipsoid, 2.5-4 cm long, fleshy; green when unripe, black when ripe, one seeded; seed hard, elongated.

Dispersal mode: Birds (barbets, bulbuls,imperial-pigeons and hornbills) and Mammals (Macaques).

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Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 49 days; 15 to 99 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1-1.5 months; later kept outside, until ready for planting in 1-1.5 years.

Prunus ceylanica

Ceylon Cherry

Synonym: *Pygeum acuminatum*
Mizo: *Rahphir, Ruphir*
Nepali: *Tarsing*

This evergreen sub-canopy tree grows up to 25 m tall, occurring mainly in elevations from 400 m to 2600 m, although in North-east India, it is seen from 100 m. The saplings are browsed by large herbivores. Adult trees appear to suffer considerable mortality due to a bark infestation. It is found throughout North-east India and peninsular India.

Flowering: June to August, ***flowers*** up to 1.2 cm long, in clusters from axil, whitish or yellowish.

Fruiting: December to February, ***fruits*** ellipsoid bilobed, 1.5-2 cm long, 2.5-3.5 cm broad, smooth; green when young, black when mature; seeds 2, hemispherical, stony.

Dispersal mode: Hill mynas, barbets, imperial-pigeons, hornbills and civets. Seeds preyed on by rodents.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 34 days; 5 to 73 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 1.5-2 months, later kept outside, until ready for planting in 1-1.5 years.

Pterygota alata

Buddha Coconut

Synonym: *Sterculia alata*
Assamese: *Kari badam*
Bengali: *Buddha narikel*
Nyishi: *Taan*

This distinctive deciduous tree has a straight bole that is free of branches for much of its length and it sometimes has buttresses. It grows up to 35 m tall and is seen up to 700 m, often in disturbed forests. The oblong-winged seeds are tightly packed into the large brown fruits. It is found throughout North-east India and peninsular India.

Flowering: March to April, ***flowers*** 1-2.5 cm across, in clusters from axils, red-brown; petals absent.

Fruiting: September to January, ***fruits*** obovoid, 12 cm long, 10 cm broad, with conical point, hairy; green when unripe, brown when ripe, many seeded; seeds elliptic, terminal wings present.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: Sowing directly.

Sowing method: Seedbeds.

Germination time: Average 23 days; 5 to 72 days.

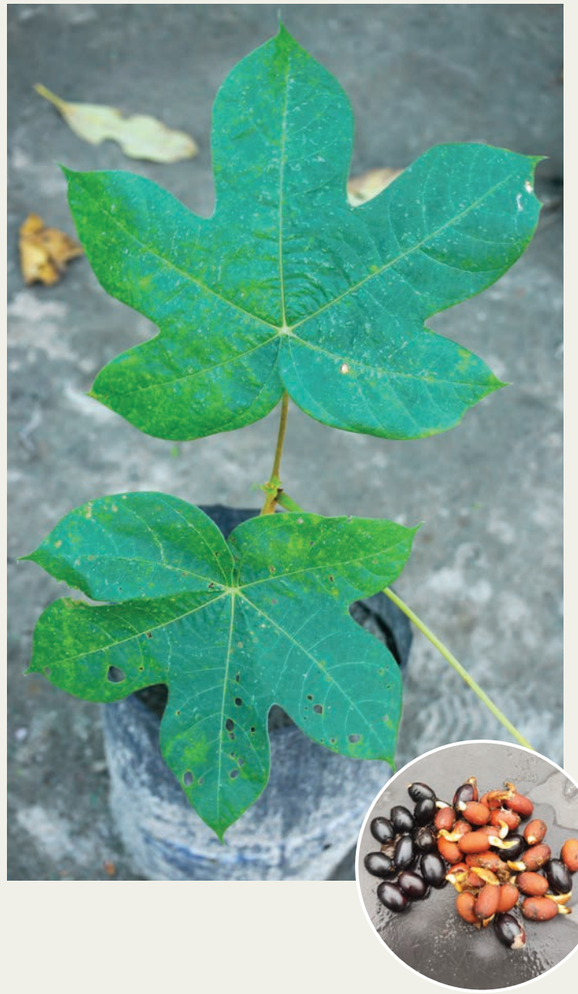
Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 2-3 months; later kept outside, until ready for planting in 1-1.5 years.

Sterculia villosa

Hairy Sterculia, Elephant Rope Tree

Assamese: *Udal*
Garo: *Ubak*
Idu Mishmi: *Aadambõ, Dukhum-bõ*
Karbi: *Chekong*
Khasi: *Dieng star*
Mizo: *Khau-pui*
Mising: *Sargik esing*
Nyishi: *Tago Sen*

This deciduous tree is often seen near rivers and stream edges and grows up to 12 m tall. The trees become leafless from March to May. It is found in Andaman Islands, throughout North-east India and peninsular India.



Flowering: January to March, ***flowers*** 0.2-0.5 cm across, in clusters from axil, yellow.

Fruiting: Unripe fruits from March, ripen from April to May, ***fruits***, a cluster of up to 5 fruitlets; kidney-shaped, 5-8 cm long, 3-5 cm broad, leathery, hairy; green when unripe, red when ripe, up to 10 seeded; seeds ovoid, covered by thin shiny papery black aril.

Dispersal mode: Hornbills, hill mynas, macaques.

Germination Methods

Pre-sowing treatment: Sowing directly.

Sowing method: Seedbeds.

Germination time: Average 10 days; 6 to 20 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1-1.5 months; later kept outside, until ready for planting in 1-1.5 years.

Stereospermum tetragonum

Fragrant Padri Tree, Yellow Snake Tree

Synonym: *Stereospermum colais*
Assamese: *Paroli*
Garo: *Bolsel*
Idu Mishmi: *Akupum-bõ, Apum-bõ*
Khasi: *Dieng sir*
Nepali: *Parhori, Jinghal*
Nyishi: *Mano*

This deciduous species is commonly seen in the lower elevations in Arunachal Pradesh and grows up to 20 m tall. Its long cylindrical pods remain on the tree for a long time. Red-breasted parakeets are often seen consuming the seeds of this species. It is found throughout North-east India and peninsular India.

Flowering: May to July, ***flowers*** showy, 2-5 cm long, in clusters at the tip of the branch, fragrant; pink.

Fruiting: September to November, ***fruits*** long, cylindrical, 35 cm long, 1-2 cm broad, 4-angled, 2-valved, dry dehiscent; green when unripe, brown when ripe, many seeded; seeds winged, compressed.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: No germination success from direct sowing of seeds. Seedlings rescued from the wild and grown.

Sowing method: Not applicable.

Germination time: Not applicable.

Time needed for sapling to be ready for planting: Polybags with the seedlings are kept under shade net for 2 months; later kept outside, until ready for planting for 1.5-2 years.

Syzygium formosum

Synonym: *Syzygium insigne*
Assamese: *Lohajam*
Karbi: *Mirte phong*
Mising: *Kurak*

This evergreen understorey tree has distinctive large leaves and grows up to 10 m tall. It grows along streams and rivers up to 300 m, often in secondary forests. The white to pinkish flowers attract many birds (drongos, lorikeets, sunbirds, spiderhunters) for the nectar. It is found in Arunachal Pradesh, Assam, Meghalaya, Nagaland, northern West Bengal.

Flowering: February to March, ***flowers*** showy, 3-4 cm across, in clusters from axil, fragrant; white.

Fruiting: May to July, ***fruits*** globose, 2.5-5 cm across, fleshy, with persistent calyx; green when unripe, white or pink when ripe, one seeded fruit; seed hard, greenish.

Dispersal mode: Possibly by birds.

Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: 11 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1.5 months approx; later kept outside, until ready for planting in 1-1.5 years.

Terminalia bellirica

Hindi: *Behera*
Bengali: *Baheda*
Assamese: *Bauri*
Khasi: *Dieng rinyn*
Nepali: *Baro*

This is a large deciduous tree that can grow up to 40 m tall, although in the wetter forests in Arunachal, the tree is often smaller (12–15 m tall). The characteristic bark is grayish. The fruits and seeds have various medicinal uses. The seeds are eaten by tree squirrels and rodents.

Flowering: May-August, ***flowers*** 0.6 cm across, greenish yellow with an unpleasant smell, in drooping clusters from axil, bisexual flowers; very small bract.

Fruiting: September-December, ***fruits*** about 2.5 cm long, globose, often abruptly narrowed to a short stalk, grey velvety, obscurely ribbed when dry.

Dispersal mode: Mammals (barking deer and sambar).

Germination Methods

Pre-sowing treatment: Pre-soaked for 2 days.

Sowing method: Seedbeds.

Germination time: Average 73 days; 9 to 158 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 2 weeks; under shade-net: 1.5-2 months approx; later kept outside, until ready for planting in 2-2.5 years.

Terminalia chebula

Black or Chebulic Myrobalan

Assamese: *Hilika, Shilika*
Bengali: *Haritaki*
Hindi: *Harra*
Idu Mishmi: *Bongolambõ*
Manipuri: *Manahi*
Nyishi: *Junkli*

This large deciduous tree is found up to 1500 m and can grow 20 m tall. Leaves are shed between November and March. The fruits are green even when ripe and consumed and dispersed by mammals such as deer. It is found throughout North-east India and peninsular India.

Flowering: April to May, up to August, ***flowers***: 0.2-0.4 cm across, in clusters at the tip of the branch or from the axil, odorous, greenish-white and pollinated by bees and other insects

Fruiting: November to March, ***fruits*** ovoid, 2.8-4.5 cm long, 1.5-2.5 cm broad, dry, smooth, rarely 2-5 angular, green when unripe, brown when ripe, one seeded; seed ovoid, hard.

Dispersal mode: Mammals (barking deer and sambar).

Germination Methods

Pre-sowing treatment: Soaking in cool water for 15-20 days, removing pulp and sowing.

Sowing method: Seedbeds.

Germination time: Average 73 days; 43-90 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 1-1.5 months; later kept outside, until ready for planting: 1-1.5 years.

Tetrameles nudiflora

False-Hemp Tree

Synonym: *Tetrameles horsfieldii*
Assamese: *Bhelu, Maina*
Bengali, Nepali: *Moina*

This is an emergent deciduous tree up to 50 m tall in the foothill forests. The long bole is often fluted with buttresses. This softwood tree often has cavities created due to storms or by bird activity. It is the most important nest tree species used by hornbills and used by many hole-nesting birds. It is found in Andaman Islands, throughout North-east India and peninsular India.

Flowering: March to April when the trees are leafless, ***flowers*** 0.2-0.5 cm long, in clusters at tip of the branch or from axil, greenish; petals absent.

Fruiting: April to May, ***fruits*** obovoid, 0.5-0.6 cm long, dotted with minute glands outside, 8 ribbed; green when unripe, yellow when ripe, many seeded; seeds minute, compressed.

Dispersal mode: Wind.

Germination Methods

Pre-sowing treatment: Very low success of germination from direct sowing of seeds. Seedlings rescued from the wild and grown. However, some seedlings of this species also come up in empty polybags on their own—these may be from seeds carried far by the wind!

Sowing method: Not applicable.

Germination time: Not applicable.

Time needed for sapling to be ready for planting (50-60 cm): Rescued wildlings placed under shade-net: 1-1.5 months; later kept outside, until ready for planting in 1 year.

Vatica lanceifolia

Lanceleaf Vatica

Assamese: *Morhal*
Nepali: *Panidhuna*

This evergreen species grows in lowland forests below 900 m and can grow up to 18 m tall. Leaf abscission followed by leaf flushing occurs in December. It has fragrant white flowers. Studies have shown that seedlings grow better in gaps or open areas than in the understorey. It is found in Arunachal Pradesh, Assam, Meghalaya, Nagaland.

Flowering: March to May, ***flowers*** 1-1.8 cm long, in clusters or solitary, fragrant; white.

Fruiting: May to July, ***fruits*** ovoid, 2-2.5 cm long, 1.5-2 cm broad, fleshy, densely hairy, with persistent calyx; green when unripe, brown when ripe, 1-2 seeded.

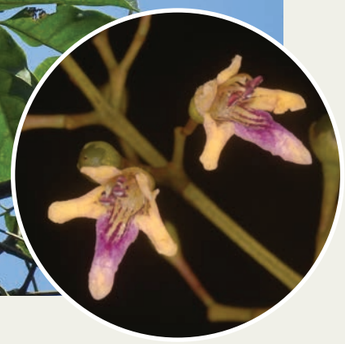
Germination Methods

Pre-sowing treatment: Removing pulp and sowing directly.

Sowing method: Seedbeds.

Germination time: Average 27 days; 6 to 87 days.

Time needed for sapling to be ready for planting: Transplanted to polybags after 7-10 days; under shade-net: 1.5 months approx; later kept outside, until ready for planting: 1-1.5 years.



Vitex quinata

Synonym: *Vitex heterophylla*
Garo: *Khungsuman, Khong-sman-bol*
Khasi: *Dieng-sart-udkhar*
Naga: *Tirale-chiang*

This evergreen tree species grows in mixed evergreen forests along streams and hilly slopes from 200 m to 1200 m. It can grow to a height of 12 m. The flowers are insect-pollinated, and the fruits are animal-dispersed. It is found in Andaman Islands, throughout North-east India and peninsular India.

Flowering: May to July, ***flowers*** in clusters at the tip of the branch, fragrant; yellowish.

Fruiting: August to September, ***fruits*** rounded, 0.8 cm diameter, fleshy; green when unripe, black when ripe, 4 seeded; seeds obovoid or oblong.

Dispersal mode: Birds (bulbuls, barbets, niltavas) and mammals (civets).

Germination Methods

Pre-sowing treatment: Sowing directly.

Sowing method: Seedbeds.

Germination time: Average 54 days; 33 to 110 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 1-2 months; later kept outside, until ready for planting in 1-1.5 years.

Zanthoxylum rhetsa

Indian Prickly Ash

Assamese: *Bajrang*
Bodo: *Bajruli*
Karbi: *Tenga nang*
Nepali: *Timur*
Nyishi: *Honyor*

This deciduous tree occurs up to 500 m in lower hills on the north bank of the Brahmaputra, grows up to 30 m tall, main stem armed with stout conical spines. Butterflies use this as a host plant. It is found in Andaman Islands, throughout North-east India and peninsular India.

Flowering: March to May, ***flowers***: 0.1-0.6 cm long, in clusters at tip of branch or from axil, white.

Fruiting: July to September, ***fruits*** globose, 0.8-1 cm diameter, fleshy, breaking into 2 valves at maturity; green when unripe, black to red when ripe, one seeded; seed shiny, globose, bluish-black.

Dispersal mode: Birds (barbets, hornbills, mynas, starlings, bulbuls, woodpeckers and laughing thrushes).
Most important seed dispersers are the red-vented bulbul and hill myna.

Germination Methods

Pre-sowing treatment: Sowing directly.

Sowing method: Seedbeds.

Germination time: Average 27 days, 24 to 32 days.

Time needed for sapling to be ready for planting (50-60 cm): Transplanted to polybags after 7-10 days; under shade-net: 4 months; later kept outside, until ready for planting in 1-1.5 years.

Forest Restoration Guidelines

Adapted from:
Mudappa, D. and Raman, T.R.S. 2010. Rainforest Restoration: A Guide to Principles and Practice. Nature Conservation Foundation, Mysore.

Forest Restoration Research Unit. 2005. How to plant a forest: the principles and practice of restoring tropical forests. Biology Department, Science Faculty, Chiang Mai University, Thailand. www.forru.org/library/0000153

How do we select species for rainforest restoration?
The primary protocol to be used for ecological restoration of rainforest is mixed native species planting of rainforest trees and some lianas and shrubs too, if available.

The species to be planted should be native species typical to the vegetation type, region, and altitude, as evidenced by their occurrence in the reference or a primary forest site.

Factors such as slope, aspect, distance to water, canopy openness, and soil status need to be considered in the selection of which seedling is to be planted at a specific location within a restoration site.

How do we get seedlings for planting?
Seed collection, nursery development and maintenance are year-round activities as the plants require continuous nurturing and because seeds of different trees become available at different times within a year.

Check the fruit ripening times of tree species in your area (details for many species given in this manual) and ensure seed collection at the right time.

Mature seeds that have fallen on the ground may be collected from forest edges or along forest trails or roads. All seeds should be from plants in the same area and the same vegetation type (species occurring in the reference sites).

Avoid collecting seeds from within forest interiors or fragments as it may negatively affect the natural process of regeneration, and forest dynamics and recovery in case of forest fragments.

If you are collecting seeds from below a parent tree, make sure that you collect only a few seeds and let the rest of the seeds remain to germinate and grow naturally.

Make sure you collect seeds from different parent trees and not just one tree to increase the genetic diversity of the species.

You can also collect seeds from animal dung (bears, civets, monkeys) or regurgitated seeds (deer, hornbills) or under perch/roost/nest trees of various animals, but do not over-collect from any single source. Leave some seeds to grow and regenerate naturally.

How do I survey a potential planting site?
All stakeholders in a forest restoration project should participate in a survey of the proposed planting site, since a wide range of issues may affect project planning and implementation, including land rights, labour inputs and any other factors. It also helps to build a consensus for the aims of the tree planting program and encourages long-term commitment.

Check the contours to determine the elevation of the site.

Look up the elevation ranges of the tree species that are being considered for planting to make sure that they can grow at the elevation of the site.

Next, use the contours and the map scale to determine the average site steepness. This will help to determine the risk of soil erosion and how easy it will be to work on the site.

Consider access to the site. Look for roads or tracks. How far away from access points will trees and planting materials have to be carried on foot?

Planting and tree care takes place mostly in the rainy season so, inspect the condition of access routes to determine if 4WD vehicles or some other form of transport for the trees and the planters may be needed.

On-site, look for sources of natural forest regeneration.

Estimate the density of naturally established trees, saplings or sprouting stumps. The number of trees planted can be reduced to compensate for the existing density of naturally established trees or sprouting tree stumps; these should not be harmed during site preparation.

Check the weed cover. If weed cover is sparse, the labour required for plot preparation can be reduced. Taller weeds must be slashed.

Examine the soil. If the soil is compacted, more labour will be needed to dig the planting holes and mulching will be essential to help improve soil structure.

Look for evidence of fire (blackened tree stumps etc.). This will help to determine what fire prevention measures may be needed like making fire lines. Also, look for signs of cattle and goats. If necessary, discuss how cattle and goats might be excluded from the site.

Take plenty of photos. These will become an invaluable historical record, when assessing the success of the project years later.

How do we deal with alien/ non-native species at the planting sites?
A basic principle is that one should strictly avoid planting alien species close to or within wildlife conservation areas.

Most restoration programs employ means of targeted removal or suppression of invasive alien species.

These may include cutting and uprooting of rootstock as in the case of *Lantana camara*, hand-weeding, pressing down of grasses with boards, or even herbicide application on specific weeds. Care should be taken in such weeding operations not to disturb the soil or native vegetation as disturbances can lead to further proliferation of weeds.

What about existing sources of forest regeneration?
First, take steps to protect any existing, naturally-established trees, seedlings, saplings or live tree stumps that may be present.

Inspect the plots thoroughly, taking care not to miss smaller tree seedlings that may be obscured by weeds.

Place a bamboo pole, painted with a bright colour, next to each plant found and dig out weeds, using a hoe, in a 1.5 m-diameter circle around each. This makes natural sources of forest regeneration more visible to workers, so they avoid damaging them when weeding or planting. It also releases natural seedlings from the competition with weeds so that they can grow beside the planted trees.

Tell everyone working in the plots the importance of preserving these natural sources of forest regeneration and to not damage or cut them during the weeding or site-preparation process.

Can fire be used to clear plots?
Definitely not. Fire kills any naturally established young trees that may be present, whilst stimulating re-growth of some perennial grasses and other weeds. It also kills beneficial micro-organisms, such as mycorrhizal fungi, and removes the possibility of using slashed weeds as mulch. Organic matter is burnt off and soil nutrients are lost in smoke. There is also a risk that fires, intended to clear a planting plot, may spread out of control to damage nearby forest or crops.

When should plots be prepared for tree planting?
Before planting, clear the plots of weeds, taking care not to damage existing native seedlings/saplings/ trees and shrubs. If weeding is done entirely with hand tools, clear plots of weeds about 1-2 weeks before planting.

How tall should the saplings be at planting time?
Some fast-growing tree species can be planted out when only about 30 cm tall, but for most species, it is better to plant them when they are about 45-75 cm tall.

Smaller saplings (less than 30 cm) have much higher post-planting mortality rates than larger ones do, because of competition with weeds, but very large saplings are much more susceptible to transplantation shock.

What is "hardening-off" and why is it necessary?
Hardening-off is the process of preparing saplings for the difficult transition from the ideal nursery environment to the harsh conditions of deforested sites. If they are not toughened up, to cope with the hot, dry, sunny conditions of planting sites, they will suffer transplantation shock and die.

About 2 months before planting, move all saplings to be planted to a separate area in the nursery and gradually reduce shade and the frequency of watering. They should stand in full sunlight for their final month in the nursery.

Watering should be gradually reduced, by approximately 50%. The aim is to slow down shoot growth, and encourage smaller new leaves. Thus, saplings normally watered in the early morning and late afternoon, should be watered just once, in the late afternoon during the hardening-off period. Saplings normally watered once a day should be watered every other day.

Do not reduce watering to the point at which leaves wilt, as that stresses and weakens saplings. Regardless of the normal schedule, water the saplings as soon as any wilting is observed.

When should trees be planted?
The best time to plant trees is early in the rainy season, once rainfall has become regular and reliable. This gives the trees the maximum length of time to grow a root system that penetrates deep enough into the soil to obtain sufficient water during the first dry season after planting to prevent desiccation. The optimal planting time in this region is mid-May to end of June, or at the onset of monsoon.

How many saplings should be delivered to the plots?
The final combined density of planted plus naturally established trees should be about 3,125 per ha, so the required number of saplings delivered to each 1 ha plot should be 3125 minus the estimated number of naturally established trees or live tree stumps.

This results in an average spacing of about 1.8-2 m between planted saplings or the same distance between planted saplings and naturally established trees (or live stumps). The distance can also be decided based on the size of the site, and the availability of saplings.
The distance is much closer than the spacing used in most commercial forestry plantations, because the objective is to ensure canopy closure, shade out weeds and eliminate the costs of weeding, as quickly as possible.
Remember, shade is the most cost-effective and environmentally friendly herbicide. Planting fewer trees would mean that weeding would have to be continued for many years and consequently total labour costs to achieve canopy closure would be higher.

If the density of trees were higher than 3125 per ha, the slower growing species would not be able to compete with faster growing ones, resulting in competitive thinning of the planted plots.

It is a waste of time to plant trees that will die anyway. Furthermore, higher planting densities would leave too little room for natural tree establishment and would thus delay recovery of tree species richness.

How many tree species should be planted?
Planting more (maximum possible) species will accelerate biodiversity recovery, since different wildlife species are attracted to different tree species.

How should saplings be transported to the planting plots?
Select only the most vigorous saplings from the nursery, after grading and hardening-off. Even saplings of the highest quality can be damaged by overheating and dehydration during transport to the site.

Furthermore, excessive movement can damage fine roots close to the sides of the containers. The shoot system may also be damaged, if the containers are not packed carefully in the vehicle.

Some basic precautions can prevent these problems.

Water the saplings just before loading them into the vehicle. Make sure containers are packed upright to prevent spillage of potting mix. If plastic bags are used, do not pack them so tightly that they lose their shape. Also, do not stack containers on top of each other, since this will crush shoots and break stems.

If an open truck is used, cover saplings with a layer of shade netting to protect them from wind damage and dehydration. Drive slowly. In the plots, place saplings upright beneath any available shade and, if possible, lightly water them again.

How far apart should saplings be planted?
Space the planting pits about 1.8-2 metres apart or the same distance away from naturally established trees or tree stumps.

Try not to position the pits in straight rows. A random arrangement will give a more natural structure to the restored forest.

Pits can be made either on planting day or a few days in advance. Use a hoe to dig a hole, approximately twice the volume of the sapling's container. At the same time, use the hoe to drag away dead weeds in a circle 50-100 cm in diameter around the hole.

How should the saplings be planted?
Mix up the species so that saplings of the same species are not planted next to each other.

If saplings are in plastic bags, slash each bag up one side with a sharp blade, taking care not to damage the root ball inside. Gently peel away the plastic bag. Try to keep the medium around the root ball intact. Place the sapling upright in the hole and pack the space around the root ball with loose soil, making sure that the sapling's root collar (the part of the stem where the roots are attached) is eventually positioned in level with the soil surface. With the palms of your hands, press the soil around the sapling stem to make it firm. This helps to join pores in the nursery medium with those in the plot soil, thus rapidly re-establishing a supply of water and oxygen to sapling's roots. For inaccessible sites with no available water, schedule planting to take place when rain is forecast. The final task is to remove all plastic bags, and garbage from the site.

CARING FOR PLANTED TREES

In deforested/degraded sites, planted trees must endure hot, dry, sunny conditions as well as competition from fast-growing weeds. In addition, during the dry season, there is a risk that fire will destroy them. Intensive care of the trees during the first 2 years after planting can significantly reduce these risks. Consequently, although caring for planted trees involves costs and hard work, it is more cost-effective than having to replant trees which die.

Provided the procedure outlined below is followed and the planted saplings are healthy, vigorous and well hardened-off, the planted forest should become self-sustaining, requiring little or no further maintenance, within 3 years and consequently, no subsequent planting should be necessary.

How often is weeding necessary?
The frequency of weeding depends on how fast the weeds grow. Weed growth is very rapid during the rainy season.

After planting, it is recommended to weed around the planted trees at least 3 times during the rainy season at 4 to 6-week intervals.

Visit the site frequently to observe weed growth. The weeding frequency can be decided based on the growth of the weeds, which differs from site to site. Carry out weeding well before the weeds grow above the height of the planted trees.

Do not carry out weeding after the end of the rainy season. This allows some weed growth to occur before the onset of the hot, dry season. This can help to shade the planted trees and prevents desiccation during the hottest period of the year.

CONTROLLING OR PREVENTING THE SPREAD OF ALIEN SPECIES

What are non-native or alien species?
Alien species of plants or animals are those species introduced intentionally or accidentally into an area where they did not previously occur by human activities. While some alien species fail to spread on their own, others can rapidly propagate and spread into newer areas. Such species are called invasive alien species and they often compete with and replace native species. Weeds are proliferating species that are usually alien and often invasive, which establish and propagate widely. Alien species are

sometimes referred to as exotics. Examples of alien species in tropical Asia include Australian tree species such as *Eucalyptus* spp. and some Acacia wattles, shrub species such as *Lantana camara* and *Mikania micrantha* from the Americas, and trees such as *Gliricidia sepium* from South America and *Spathodea campanulata* from Africa.

Why should we deal with alien species?

Many alien species (e.g., *Eucalyptus* spp., *Acacia auriculiformis*, *Acacia mearnsii*, pines) have been planted widely, even inside wildlife sanctuaries and national parks. In addition, many herbaceous weeds have been introduced and spread due to various human activities and regular small-scale disturbances. Sometimes alien species have been planted as they are considered to provide food for wildlife (e.g., *Maesopsis eminii*).

These alien species have various detrimental effects on natural ecological processes, native vegetation, and many wildlife populations through: Reduction in ground water table (e. g., *Eucalyptus* spp.); alteration of soil characteristics and microclimate; suppression or alteration of native plant communities (e.g., *Maesopsis eminii*); proliferation of other weeds (e.g., *Lantana camara* often grows in the understorey of *Eucalyptus* plantations); change in forest structure and function (many alien species); invasion into surrounding landscape (many alien species, *Acacia mearnsii*, *Spathodea campanulata*); reduction in native biological diversity, particularly affecting specialized mature forest animal species.

How do we deal with alien species?

A basic principle is that one should strictly avoid planting alien species close to or within wildlife conservation areas. Alien species need to be dealt with care. Most restoration programmes employ means of targeted removal or suppression of invasive alien species. These may include cutting and uprooting of rootstock as in the case of *Lantana camara*, hand-weeding, pressing down of grasses with boards, or even herbicide application on specific weeds. Care should be taken in such weeding operations not to disturb soil or native vegetation as disturbances can lead to further proliferation of weeds. Occasionally some alien species may prove useful in restoration, if they are non-invasive, by providing partial shade or leaf litter that may act as mulch.

Can monoculture plantations be ecologically restored?

Experience from restoration projects and regeneration studies indicate that it is possible to restore rainforests in sites currently dominated by alien species. In sites under *Eucalyptus* and *Maesopsis* tree canopies, for instance, restoration efforts by removal of herbaceous understorey weeds (without cutting native vegetation) and planting of a diversity of native species has proved quite successful in the Valparai region, Western Ghats. Some monoculture plantations, if protected from disturbances such as fire, develop a diverse regeneration of native plant species when they are close to seed sources (natural forests). The diversity of species is, however, usually lower than in relatively undisturbed forests.

Alien or non-native species in North-east India

We provide below a list of some major invasive alien species (herbs and shrubs) that need to be controlled in forest and other natural habitats. This is not an exhaustive list.

Major invasive plant species in North-east India

Ageratum conyzoides
Goatweed

Ageratina adenophora
Crofton weed

Alternanthera sessilis
Sessile joyweed

Alternanthera tenella
Joyweed/Joseph's coat

Argemone mexicana
Mexican prickly poppy

Bidens pilosa
Black-jacks/Cobblers pegs

Cassia alata
Candlebush/Empress candle plant

Senna (Cassia) obtusifolia
Sicklepod

Senna (Cassia) tora
Sickle Senna

Senna (Cassia) occidentalis
Coffee Senna

Chamaesyce (Euphorbia) hirta
Asthma plant

Chromolaena odorata
Siam weed/Devil weed/Jack-in-the-bush

Datura innoxia
Angel's Trumpet

Eclipta prostrata
False daisy

Maesosphaerum (Hyptis) suaveolens
American mint/Bush mint

Pontederia (Eichornia) crassipes
Common water hyacinth

Ipomea carnea
Bush morning glory

Ipomea aquatica
Water morning glory/Water spinach

Lantana camara
West Indian Lantana

Ludwigia peruviana
Primrose willow

Mikania micrantha
Bittervine/Climbing hempweed/ Mile-a-minute weed

Mimosa invisa & Mimosa invisa inermis
Touch-me-not

Parthenium hysterophorus
Congress grass/Carrot grass/ White-top weed/Famine weed

Pistia stratiotes
Water lettuce

Salvinia molesta
Buttonweed

Solanum carolinense
Carolina horsenettle

Solanum torvum
Turkey berry

Solanum viarum
Tropical soda apple

Stachytarpheta indica
Indian snakeweed

Stachytarpheta jamaicensis
Blue snakeweed

We have provided a list of some major alien tree species that have either been deliberately planted along roadsides, in plantations, in urban areas and in forests or accidentally brought into natural habitats in North-east India. While some of these are not invasive, they should be strictly avoided and not used in restoration (or in any sort of plantation activities). This is not a complete list.

Alien Tree species

1. *Acacia auriculata*
2. *Acacia mearnsi* (invasive)
3. *Cassia javanica*
4. *Conocarpus erectus*
5. *Cordia sebestena*
6. *Delonix regia*
7. *Eucalyptus* spp.
8. *Gliricidia sepium*
9. *Peltophorum pterocarpum*
10. *Plumeria alba*
11. *Leucaena leucocephala*
12. *Roystonea regia*
13. *Samanea saman*
14. *Senna (Cassia) siamea*
15. *Spathodea campanulata* (invasive)
16. *Swietenia macrophylla*
17. *Terminalia mantaly*
18. *Thevetia peruviana*
19. *Thespesia populnea*

There are some native species that occur in other parts of India that should not be planted inside the tropical semi-evergreen/evergreen forests in Arunachal Pradesh—such as *Erythrina variegata*, *Terminalia arjuna*, *Lagerstroemia indica*, *Lagerstroemia speciosa*, *Tectona grandis*, *Phyllanthus emblica* and *Pongamia pinnata*. But some of these species occur naturally in parts of Assam. In addition, often guava, lemon, mango (cultivated varieties) are planted inside forests during afforestation/plantation activities. These should be avoided.

Bombax ceiba, which is an ecologically important native tree species (included in the list in this book) also should not be planted inside forests. This species usually grows along the forest edge and riverine habitat.

The biogeography of the Eastern Himalayan and NE Indian hills are distinct and shaped by rivers, terrain, and other factors, therefore species should ideally be grown from seeds sourced locally or if saplings are procured they should be taken from nearby local nurseries. Species such as *Shorea assamica* and *Dipterocarpus macrocarpus* which occur only on the south bank of the Brahmaputra should not be planted north of the river and those that only occur on the north bank should not be planted south of the river. Ideally, for species that occur on both sides of the Brahmaputra, saplings from the northern and southern parts of Brahmaputra should not be mixed, as even if species may appear morphologically similar, their populations could be genetically distinct, and genotype mixing can negatively impact populations.

Table 1.

List of main species grown at the NCF nursery, Darlong, Arunachal Pradesh.

No.	Family	Scientific name	Local names	Fruiting months
1	Lauraceae	***Actinodaphne obovata***	Assamese: Pati-khunda, Noga-bagnola, Paji-huta, Petarichowa; Nepali: Runchepat	April-November
2	Fabaceae	***Adenanthera pavonina***	Assamese: Jungli chandan; Bengali: Ranjana	September-December
3	Meliaceae	***Aglaia spectabilis***	Assamese: Amari, Lali; Bengali: Lali	May-August
4	Simaroubaceae	***Ailanthus integrifolia***	Assamese: Borpat	April-May
5	Cornaceae	***Alangium chinensis***	Assamese: Sika moroliya; Boga amruliya, Bogalmoni, Maroli goch; Nepali: Bhalu paile	July-November
6	Phyllanthaceae	***Antidesma montanum***	—	August-November
7	Mimosaceae	***Albizia procera***	Assamese: Koroi; Nyishi:Tale	June-December
8	Mimosaceae	***Albizia lucidior***	Assamese: Moj, Potka Siris	September-January
9	Apocynaceae	***Alstonia scholaris***	Assamese: Chatiana; Bengali: Chhatim, Saptaparni	January-February
10	Meliaceae	***Aphanamixis polystachya***	Assamese: Hakhori Bakhori	October-April
11	Thymelaeaceae	***Aquilaria malaccensis***	Agar	June-July
12	Mimosaceae	***Archidendron bigeminum***	Assamese: Bachahu; Hindi: Kachlora	April-May
13	Moraceae	***Artocarpus chaplasha***	Assamese: Shamkathal; Nyishi: Lamia	March-July
14	Phyllanthaceae	***Baccaurea ramiflora***	Assamese: Leteku, Kusum tenga;	May-August
15	Euphorbiaceae	***Balakata baccata***	Assamese: Selleng, Mota Selleng, Lewa; Bengali: Chota-mal; Nepali: Ankhataruwa	July-September
16	Fabaceae	***Bauhinia purpurea***	Assamese: Kanchan, Koiral	January-March
17	Lauraceae	***Beilschmiedia assamica***	Assamese: Amchoi, Kanthal-patia; Nepali: Tarsing	October-November
18	Lauraceae	***Beilschmiedia* sp. 1**	—	December-March
19	Lauraceae	***Beilschmiedia* sp. 2**	—	February-September
20	Lauraceae	***Beilschmiedia* sp. 3**	—	April-August
21	Phyllanthaceae	***Bischofia javanica***	Assamese: Urium; Bodo: Thaiso; Nyishi: Mebu	September-January
22	Bombacaceae	***Bombax ceiba***	Assamese: Semal; Bengali: Shimul; Nyishi: Sangdo	March-May
23	Phyllanthaceae	***Bridelia stipularis***	Bengali: Harinhara; Dimasa: Sepaph; Karbi:Thepi	February-March
24	Burseraceae	***resiniferum***	Assamese: Dhuna, Lal dhuna; Nyishi: Sanglam	August-March
25	Burseraceae	***Canarium strictum***	Assamese: Dhuna, Kala dhuna; Nyishi: Sanglam	October-February
26	Fagaceae	***Castanopsis indica***	Assamese: Hingori	September-November
27	Fagaceae	***Ceriscoides campanulata***	Assamese: Bitmara, Bih-mona, Dieng-chh; Bodo: Gandhapaji	November-January
28	Meliaceae	***Chisocheton cumingianus***	Assamese: Banderdima; Nyishi: Poyo nyikfe	March-July
29	Anacardiaceae	***Choerospondias axillaris***	Assamese: Lepchipoma; Nepali: Lapsi; Nyishi: Balam	July-October
30	Meliaceae	***Chukrasia tabularis***	Assamese: Bogipoma; Bengali: Chikrassi; Nyishi: Balam	October-February
31	Lauraceae	***Cinnamomum bejolghota***	Assamese: Jungli tezpat, Patihonda, Noga-dalcheni	June-July
32	Rutaceae	***Citrus* sp.**	—	October-March

33	Lauraceae	***Cryptocarya amygdalina***	Assamese: Khorika sopa, Bon jalokia, Bonsum	July-August
34	Staphyleaceae	***Dalrympelea pomifera***	Assamese: Pani amora	June-August
35	Dilleniaceae	***Dillenia indica***	Assamese: Outenga; Bengali: Chalta; Nyishi: Jampa, Sompa, Bauu	November-April
36	Lythraceae	***Duabanga grandiflora***	Assamese: Khokun; Bengali: Bondorphulla; Nepali: Lampate; Nyishi: Dabey	April-October
37	Meliaceae	***Dysoxylum cauliflorum***	Assamese: Goborkhutla	April-May
38	Meliaceae	***Dysoxylum gotadhora***	Assamese:Banderdima; Bengali: Borogotadhora; Nyishi: Poyo nyikfe	February-May
39	Meliaceae	***Dysoxylum procerum***	Assamese: Amselleng, Lali	November-April
40	Elaeocarpaceae	***Elaeocarpus aristatus***	Assamese: Phulchampa; Gohorisopa	June-September
41	Elaeocarpaceae	***Elaeocarpus sphaericus***	Assamese: Rudraksh	October-November
42	Elaeocarpaceae	***Elaeocarpus sikkimensis/varunua***	Assamese: Seleng	June-August
43	Euphorbiaceae	***Endospermum chinense***	Assamese: Phulgamari	August-November
44	Moraceae	***Ficus drupacea***	Assamese: Dabor (generic for figs)	January-April
45	Moraceae	***Ficus nervosa***	Assamese: Chepani-dimoru, Khanpati dimoru, Kharipati-dimoru	Throughout the year, peak in July-September
46	Burseraceae	***Garuga floribunda***	Assamese: Kechkechipoma, Bon misiri	June-November
47	Lamiaceae	***Gmelina arborea***	Assamese: Gamari	May-September
48	Achariaceae	***Gynocardia odorata***	Assamese: Chalmugra, Bonsha, Lemtem; Bengali: Chaulmugra; Garo: Sikelupi; Nepali: Gandare, Koitur	November-January
49	Areliaceae	***Heteropanax fragrans***	Assamese: Gaikhure, Koronda, Koroinga, Keseru	January-March

50	Myristicaceae	***Horsfieldia kingii***	Assamese: Ramtamul: Bengali: Ramsupari; Nyishi: Mouru sangphu	February-May
51	Myristicaceae	***Knema erratica***	Assamese: Bhela	March-June
52	Altingiaceae	***Liquidambar excelsa***	Assamese: Jutuli; Hindi: Rasamala	August-November
53	Lauraceae	***Litsea monopetala***	Assamese: Muga, Sualu, Khuwalu, Bon-khuwalu; Bengali: Bara-kukurchita; Nepali: Kutmira, Katamero	June-August
54	Lauraceae	***Litsea panamanja***	—	May-August
55	Arecaceae	***Livistona jenkinsiana***	Assamese: Tokko, Toko pat; Nyishi: Tah	September-February
56	Euphorbiaceae	***Macaranga indica***	Assamese: Jaglo; Nyishi: Hech Hara	Winter
57	Magnoliaceae	***Michelia champaca***	Assamese: Titachampa	September
58	Magnoliaceae	***Magnolia hodgsonii***	Assamese: Boromthuri; Nyishi: Parampare	May-November
59	Euphorbiaceae	***Mallotus tetracoccus***	Assamese: Loru-bondha, Morolia	August-December
60	Callophylaceae	***Mesua ferrea***	Assamese: Nahar; Hindi: Nag champa, Nag kesar	March-October
61	Rutaceae	***Micromelum integerrimum***	Nyishi: Sutum tanyi	July-September
62	Annonaceae	***Monoon simiarum***	Assamese: Kari, Boga-khamtoi, Boga-koliori	May-July; December-February
63	Moraceae	***Morus macroura***	Assamese: Bola	April-June
64	Oleaceae	***Olea dioica***	Assamese: Poreng, Bon-bhaluka; Bengali: Atta jam	February-April
65	Bignoniaceae	***Oroxylum indicum***	Assamese: Totola, Toguna; Bengali: Shona; Hindi: Bhut vriksha; Nyishi: Laata; Tangkhul: Phong	October-December
66	Lauraceae	***Phoebe cooperiana***	Assamese: Mekahi; Nyishi: Sanchar, Sangcher	June-August

67	Lauraceae	***Phoebe goalparensis***	Assamese: Bonsum	May-July
68	Simaroubaceae	***Picrasma javanica***	Assamese: Kalakari, Neem-tita, Bon poshla; Nyishi: Taan	May-December
69	Rosaceae	***Prunus ceylanica***	None	December-February
70	Sterculiaceae	***Pterygota alata***	Assamese: Kari badam; Bengali: Buddha narikel; Nyishi: Taan	September-January
71	Theaceae	***Pyrenaria barringtoniifolia***	Assamese: Jungli-cha; Jungli-togor; Bon madhuri	October-February
72	Elaeocarpaceae	***Sloanea sterculiacea***	Assamese: Phul hingori, Bandarnema	October-December
73	Anacardiaceae	***Spondias pinnata***	Assamese: Amora tenga, Amora; Bengali:Aamraata, Aamraataka; Nepali: Amaro; Tangkhul: Khursongthei	November-February
74	Sterculiaceae	***Sterculia villosa***	Assamese: Udal; Nepali: Khava, Odani	April-May
75	Bignoniaceae	***Stereospermum tetragonum***	Assamese: Paroli; Nepali: Parhori, Kuber bacha, Jinghal; Nyishi: Mano	September-November
76	Myrtaceae	***Syzygium cumini***	Assamese: Jamun, Kola-jamu, Bor-jamu	May-July
77	Myrtaceae	***Syzygium formosum***	Assamese: Lohajam	May-July
78	Combretaceae	***Terminalia bellerica***	Assamese: Behera	September-December
79	Combretaceae	***Terminalia chebula***	Assamese: Hilika, Shilika; Bengali: Haritaki; Hindi: Harra	November-March
80	Tetramelaceae	***Tetrameles nudiflora***	Assamese: Bhelu, Maina	April-May
81	Dipterocarpaceae	***Vatica lanceifolia***	Assamese: Morhal, Nepali: Panidhuna	May-July
82	Lamiaceae	***Vitex quinata***	Panchpatti	August-September
83	Rutaceae	***Zanthoxylum rhetsa***	Assamese: Bajrang; Bodo: Bajruli; Bodo: Bajruli	July-September

An additional 27 species have been raised in very small numbers.

Table 2.

Survival percentage of 32 tree species after 18 months at a restoration site inside Pakke Tiger Reserve, Arunachal Pradesh, India. Species were classified into different categories of survival following Raman et al. (2009).

No.	Species	Family	Dispersal mode	No. of saplings planted	Percentage survival after 18 months	Species classification
1	***Pterygota alata***	Malvaceae	Wind	35	94.3	Excellent
2	***Syzygium formosum***	Myrtaceae	Animal	67	86.6	Excellent
3	***Monoon simiarum***	Annonaceae	Animal	169	85.2	Excellent
4	***Cryptocarya amygdalina***	Lauraceae	Animal	414	82.1	Excellent
5	***Dysoxylum gotadhora***	Meliaceae	Animal	312	82.1	Excellent
6	***Litsea* sp. 2**	Lauraceae	Animal	20	80	Excellent
7	***Beilschmiedia* sp. 3**	Lauraceae	Animal	61	73.8	Good
8	***Aglaia spectabilis***	Meliaceae	Animal	126	68.3	Good
9	***Phoebe* sp.**	Lauraceae	Animal	71	66.2	Good
10	***Beilschmiedia* sp. 2**	Lauraceae	Animal	47	63.8	Good
11	***Actinodaphne obovata***	Lauraceae	Animal	33	63.6	Good
12	***Mesua ferrea***	Calophyllaceae	Mechanical	24	62.5	Good

13	***Beilschmiedia* sp. 1**	Lauraceae	Animal	103	62.1	Good
14	***Chisocheton cumingianus***	Meliaceae	Animal	132	62.1	Good
15	***Chukrasia tabularis***	Meliaceae	Wind	108	61.1	Good
16	***Bauhinia purpurea***	Leguminosae	Wind	125	59.2	Good
17	***Elaeocarpus sphaericus***	Elaeocarpaceae	Animal	33	54.5	Good
18	***Tetrameles nudiflora***	Tetramelaceae	Wind	139	53.2	Good
19	***Adenanthera pavonina***	Leguminosae	Animal	40	52.5	Good
20	***Magnolia hodgsonii***	Magnoliaceae	Animal	41	46.3	Moderate
21	***Sterculia villosa***	Malvaceae	Animal	43	44.2	Moderate
22	***Gmelina arborea***	Lamiaceae	Animal	36	41.7	Moderate
23	***Prunus ceylanica***	Rosaceae	Animal	61	39.3	Moderate
24	***Artocarpus chaplasha***	Moraceae	Animal	145	36.6	Moderate
25	***Litsea monopetala***	Lauraceae	Animal	18	33.3	Moderate
26	***Dysoxylum procerum***	Meliaceae	Animal	24	29.2	Moderate
27	***Phoebe cooperiana***	Lauraceae	Animal	242	28.9	Moderate
28	***Beilschmiedia assamica***	Lauraceae	Animal	33	27.3	Moderate
29	***Bombax ceiba***	Lauraceae	Wind	19	26.3	Moderate
30	***Horsfieldia kingii***	Myristicaceae	Animal	175	25.7	Poor
31	***Picrasma javanica***	Simaroubaceae	Animal	36	19.4	Poor
32	***Choerospondias axillaris***	Anacardiaceae	Animal	11	9.1	Poor

Sourcing Seeds

Seeds can also be sourced from seeds dispersed by birds and mammals but please DO NOT collect all. Leave behind some seeds to germinate and grow on-site in the forest.

Seedling of *Canarium resiniferum* germinating from a pile of seeds regurgitated by deer.

Seedling of *Bridelia stipularis* germinating from a civet scat on a log.

Seeds of *Canarium resiniferum* regurgitated by sambar at a resting site.

Seedling of *Citrus* sp. germinating in elephant dung

Seeds of *Ficus* sp. in hornbill droppings.

Seeds of many different species are regurgitated by hornbills below roost trees.

Seeds of *Gynocardia odorata* deposited by civets on a tree trunk.

Tiny fig seeds in a civet scat deposited on a log.

Seeds of *Cyathocalyx* sp. deposited by civets on a tree trunk.

Clump of seeds of *Bridelia stipularis* in a civet scat.

Thousands of fig seeds in wild pig droppings.

Seeds of many species are regurgitated by hornbills below its nest tree.

Seeds regurgitated by hornbills below a nest tree along with regenerating seedlings.

The seeds that hornbills regurgitate are cleaned of all pulp and have a pink color when freshly dropped.

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References

Borawake, N., Datta, A., & Naniwadekar, R. 2021. Tropical Forest Restoration in the Eastern Himalaya: Evaluating Early Survival and Growth of Native Tree Species. Ecological Restoration, 39(3), 52-63. https://doi:10.3368/er.39.3.194

Borawake, N., Datta, A. & Naniwadekar, R. 2023. Tropical forest restoration in the Eastern Himalaya. Progress Report (2014-2023). Nature Conservation Foundation. 45 pp.

Forest Restoration Research Unit. 2005. How to plant a forest: the principles and practice of restoring tropical forests. Biology Department, Science Faculty, Chiang Mai University, Thailand. www.forru.org/library/0000153

Mudappa, D. and Raman, T.R.S. 2010. Rainforest Restoration: A Guide to Principles and Practice. Nature Conservation Foundation, Mysore. www.ncf-india.org/western-ghats/52

Page, N., Datta, A. and Basu, B. 2022. Trees of Arunachal Pradesh: A field guide. Nature Conservation Foundation. January 2022, 591 pp. Downloadable as a pdf at:
www.ncf-india.org/eastern-himalaya/trees-of-arunachal
Hard copy can be purchased at:
ncf-store.zohocommerce.in/products/trees-of-arunachal-a-field-guide/1638627000000207578

Websites & Online Resources

Ecological Restoration Alliance: www.era-india.org
www.ncf-india.org/western-ghats
www.ncf-india.org/eastern-himalaya/restoration-of-hornbill-habitats
www.facebook.com/pages/Ecoagriculture-India/333535013922
www.ser.org
www.lets-plant.org/databases
www.wri.org/initiatives/global-restoration-initiative
www.gbsanctuary.org

Annexure

Nursery techniques for more tree species

The manuals listed below provide nursery techniques for growing 29 native tree species in North-east India, two species do not occur in North-east India.

Singh, U.V, Ahlawat, S.P & Bisht, N.S. 2003. Nursery techniques of local tree species. SFRI Information Bulletin No. 9. State Forest Research Institute, Dept of Environment & Forests, Government of Arunachal Pradesh, Itanagar.

Singh, U.V, Ahlawat, S.P & Bisht, N.S. 2003. Nursery techniques of local tree species II. SFRI Information Bulletin No. 11. State Forest Research Institute, Dept of Environment & Forests, Government of Arunachal Pradesh, Itanagar. www.doc-developpement-durable.org/file/Culture/Arbres-Bois-de-Rapport-Reforestation/graines-Plantations/nursery_techniques.pdf

The 24 species listed below occur in the low-elevation forests of Arunachal Pradesh, Assam and some other states in North-east India.

1. *Acrocarpus fraxinifolius* Mandani
2. **Adenanthera pavonina* Jungli chandan
3. **Aglaia spectabilis* (*Amoora wallichii*) Amari
4. **Ailanthus grandis* Borpat
5. ***Altingia excelsa* Jutuli
6. **Artocarpus chaplasha* Sam Kathal
7. **Aquilaria malaccensis* Agar
8. **Bischofia javanica* Urium
9. ***Bridelia retusa* Kuhir
10. **Chukrasia tabularis* Bogipoma
11. ***Duabanga grandiflora* Khokun
12. **Elaeocarpus aristatus* Gahorisopa
13. ***Elaeocarpus floribundus* Jalpai

14. **Elaeocarpus sphaericus* Rudraksh
15. **Mesua ferrea* Nahar
16. **Michelia champaca* Titasopa
17. **Morus laevigata* Bola
18. *Neolamarckia cadamba* Kadam (more in forest edge in North-east India)
19. **Phoebe cooperiana* Mekahi
20. *Phoebe goalparensis* Bonsum
21. **Canarium strictum* Dhuna/Kaladhuna
22. ***Schima wallichi* Makri sal
23. **Spondias pinnata* Amora tenga
24. *Terminalia myriocarpa* Hollock

**Indicates species we have grown in our nursery.*

***Indicates species we have tried to grow but not been able to raise or have grown in very small numbers in our nursery.*

Other species in the SFRI manuals include:
Dipterocarpus macrocarpus Hollong (only south bank of Brahmaputra)
Shorea assamica Mekai (only south bank of Brahmaputra)
Albizia arunachalensis (julibrissin) Siris
Alnus nepalensis Alder (in subtropical forests above 500 m)
Michelia (Magnolia) kisopa Chobsi
Mimusops elengi Bokul (occurs up to western Assam)
Sapindus emarginatus Ritha/Manisal (does not occur in North-east India)

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