Erythrophloeum fordii Oliver

Ecology and silviculture in Vietnam

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CIFOR

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Preface

Smallholders plant a wide range of tree species. In Vietnam, much of the planting involves the use of fast growing trees geared towards the production of raw materials for the pulp and paper industry and woodchips. Vietnam's environmental policy puts much emphasis on restoring forest ecosystems, protecting ecological environments and conserving biodiversity, in particular indigenous species. The Vietnamese government is carrying out a large scale 'reforestation' programme with the aim of improving local livelihood security, environmental sustainability and industrial wood supply. Smallholders are involved in plantation timber production through various schemes.

In general, smallholder plantations are successful but farmers often lack the appropriate technical knowledge for efficient tree management. The harvesting of forest products is usually the primary management activity, with other practices being less frequently conducted. As a consequence, growth rates may be suboptimal. The productivity of smallholder plantations can be improved by enhancing smallholders' management knowledge and skills, including species selection (site matching), silvicultural management to produce high quality products, and pest and disease management.

This manual is 1 of a series of 5 produced as part of the research project 'Strengthening Rural Institutions to Support Livelihood Security for Smallholders Involved in Industrial Tree-Planting Programmes in Vietnam and Indonesia', a scheme coordinated by the Centre for International Forestry Research (CIFOR). This project is funded by the Advisory Service on Agriculture Research for Development (BMZ/BEAF), through the German agency for international cooperation, Gesellschaft für Internationale Zusammenarbeit (GIZ) for the period 2008–2011. This manual brings together a wealth of information on *Erythrophloeum fordii* Oliver from a variety of different sources, with particular relevance to Vietnamese sites. However, in terms of growth and yield aspect, data for this species is limited, particularly from smallholder plantations. A concerted effort has been made to collect inventory data from research sites in smallholder indigenous species plantations in Phu Tho Province, Vietnam.

We believe this manual offers valuable assistance to smallholders and organisations involved in implementing tree planting programmes.

The authors

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1. Introduction

Erythrophloeum fordii, the so-called 'ironwood', is a tree species indigenous to Vietnam which produces high quality timber. This species has been exhausted by heavy exploitation and deforestation and is rare in Vietnam. Aside from its economic objectives, the Government of Vietnam's Five Million Hectare Reforestation Project aims to protect the environment, restore forest ecosystems and conserve biodiversity. The preservation of native indigenous species is of special significance to the country (FSIV and JICA 2000).

Figure 1. *Erythrophloeum fordii* leaves
Photo by Nguyen The Dzung

2. Description of the species

2.1 Taxonomy

Botanical name: *Erythrophloeum fordii* Oliver
Family: Caesalpiniaceae
Subfamily: Caesalpinioideae
Vernacular/common name in Vietnam: Lim Xanh

2.2 Morphological characteristics

Erythrophloeum fordii is a large, evergreen tree species which is capable of reaching a height of 37–45 m and a diameter of 200–250 cm. The stem is rounded with dark brown bark, which is square cracking, has many conspicuous lenticels and can be peeled off in scales. The base of the stem has a small buttress. The foliage is thick and green all year round. The leaves are bipinnate and ovoid, with a rounded base and pointed tip. Their upper layer is dark green, whereas the lower layer is pale green with conspicuous veins. The inflorescence is apical racemose and 20–30 cm long with small, white flowers which open in March–April. The fruit is an oblong-elliptic pod, 15–30 cm long, which contains 6–12 seeds. Fruits ripen in December–January and are brown or greyish black. The seeds are large, flat and square-shaped with a pointed tip, and grow at an obtuse angle. The seed coat is hard and black (JICA 1996).

2.3 Distribution

Erythrophloeum fordii is distributed across the south of China (including eastern Taiwan) and the north of Vietnam. It occupies elevations of 300–900 m.

Erythrophloeum fordii is indigenous to Vietnam and is distributed across Bac Giang, Da Nang, Ha Tay, Hoa Binh, Lang Son, Nghe An, Ninh Binh, Phu Tho, Quang Binh, Quang Nam, Quang Ninh, Quang Tri, Thai Nguyen, Thanh Hoa, Tuyen Quang, Vinh Phuc and Yen Bai provinces, and is also found in Ham Tan (Binh Thuan Province). It grows between 10° 47' N and 23° N, and 102°–108° E, but distribution is concentrated at 17°–23° N (FSIV and JICA 2003).

Original climate conditions are:

Average annual rainfall: 1500–2800 mm
Rainy season (≥100 mm/month): 6–7 months
Average annual temperature: 22.0–24.8 °C
Average highest temperature in the hottest month: 31.7–33.8 °C
Average lowest temperature in the coldest month: under 14 °C (Kha 2004).

2.4 Ecological range

Erythrophloeum fordii grows in many kinds of soil, and can develop in various types of mother soil such as sandstone, shale, mica schist and even soil with a mechanical composition ranging from light to heavy. It can tolerate high humidity, an average to high acidic content, and site conditions which have a humid and deep soil layer. It usually grows with many other broad leaved tree species in a multi-storeyed forest environment, where vegetation is rich (FSIV and JICA 2003).

2.5 Wood characteristics

Research conducted in Southern Fujian assessed the physical and mechanical properties of *Erythrophloeum fordii* wood, which is of high density and has good capacity for deformation. The air-dried density was 0.857 g/cm^3, the basic density was 0.746 g/cm^3 and the shrinkage coefficient of volume was 0.615. The compression strength parallel to grain was 67.59 MPa, the bending strength parallel to grain was 141.82 MPa and the composite strength was 209.41 MPa (Fang 2006).

2.6 Uses

Erythrophloeum fordii wood is a precious timber: It has fine veins, is hard, strong, durable, weather resistant and seldom curves or cracks. The specific density of dry wood is 930 kg/m^3. The wood has high structural strength and is much sought after for use as flooring planks and in construction, as well as in certain infrastructure and transport capacities where long durability is required (FSIV and JICA 2003).

Figure 2. Furniture made from *Erythrophloeum fordii* wood
Photo by Nguyen The Dzung

3. Seed production

3.1 Seed collection

Seeds should be collected from mother plants that exhibit good growth patterns, have thickly proportioned foliage, a round, straight trunk of 40 cm diameter or more, and have no pests or other natural flaws. The optimum time for seed collection is as soon as the seeds reach maturation. This happens in October–December, when the skin of the fruit is a grey brown and the seeds have turned shiny black and have hardened. If not collected then, the seed may over-ripen and not germinate well, or be susceptible to insect attack if fruits or pods stay on the tree too long. Seed collection should be conducted when pods or fruits are still on the tree.

3.2 Seed preparation

Processing *Erythrophloeum fordii* seeds is a difficult task as they have hard skin and are covered by a firm film, thus making it difficult for them to absorb water. To solve this problem, one of the following methods can be employed.

Mechanical processing combined with heating. The seeds should be rubbed on hard rough surfaces to create deep scratches, or a sharp knife should be used to cut a corner of the seeds. Once this has been done, the seeds should be soaked in warm water (60 °C) for 6–8 hours. All the film should be washed from around the seeds and they should be stored in a cloth bag. The seeds should be washed every day for 10–12 days, after which they should germinate. Those seeds which exhibit cracks should be chosen for sowing.

High temperature combined with chemical processing. The seeds should be soaked in potassium permanganate 0.1% for 30 minutes, then transferred to warm, weak vinegar dissolved in water, for 1–2 hours. Next the seeds should be poured out into big, open baskets and rubbed hard to remove the film. Once this has been done, the seeds should be soaked in boiling water (100 °C) then left to cool down and stand for 10–15 hours. At this point, those seeds which are enlarged should be selected and put into a cloth bag to keep warm until they begin to crack. Seeds that still have not enlarged after soaking could be soaked for another 3–4 hours.

3.3 Seed storage and viability

Erythrophloeum fordii seeds can be stored using one of the following methods:

Dry storage in a suitable room. Put all the seeds in cloth bags and place them in jars or wooden tanks with a small amount of lime powder to encourage desiccation. Seeds can be stored this way for 1–2 years.

Dry storage in a cold store. Put the seeds in polyethylene bags with silica gel for desiccation and store at 5–10 ˚C. Seeds can be stored this way for over 3 years.

Number of seeds per kilogramme: 9500–11 000
Primary germination rate: over 80%
Germination rate after storage: 60–70%

4. Propagation and planting

4.1 Sowing and transplanting

Following appropriate preparation the seeds can be sown either in pots or in beds.

Sowing into pots. Use a pointed stick to drill a hole 1–2 cm deep in the soil in the middle of the pot, then put in a seed and cover it with soil. The number of seeds per pot determines the security of successful germination: e.g. 3 seeds 40–60%, 2 seeds 60–90%, 1 seed > 90%. Use sterilised straw to cover the pots and maintain humidity. Water once a day with 3–4 litres/m^2 to keep seeds moist after sowing.

Sowing into beds. The soil in the beds should be carefully prepared for sowing. Create a bed surface 0.8–1.0 m wide and cover it with 3–5 cm of fine sand. About 5–7 days before sowing, spray the seeds with Viben C 0.3% to prevent collar rot. A day before sowing, water the beds to keep them damp. Seeds should be sprinkled evenly onto beds, at 1 kg of seeds for every 8–10 m^2, and then covered with a 1–2 cm layer of fine soil. Afterwards, cover the bed surface with sterilised straw. The seeds should be watered every day using about 4 litres/m^2 each time. The beds need to be shaded so that the plants only receive 20–30% sunlight. When the seeds have germinated, they should be transplanted into pots

Transplanting seedlings into pots. Shoots of 1.0–1.5 cm long should be transplanted during cool weather or in light rain, whereas days of strong sunlight or heavy rain should be avoided. Each pot should consist of 85–89% upper layer soil, 10–15% manure and 1% phosphate. Pots should measure 9 × 13 cm and should have root-training ridges. The pots should be dampened with water one day before transplanting. Use a pointed stick to drill holes in the middle of the soil of each pot, deep enough for the shoots. The shoots should be inserted so that their collars are at the pot's surface. Sticks should be used to press the soil down around the shoots.

Care for the seedlings. After transplanting, it is important to shade the plants, as they can only tolerate 10–20% sunlight during their first stages of growth. After one month, the shading could be reduced to allow 30% sunlight to filter through, and after 45 days it can be removed completely. The plants should be watered once a day for the first 15

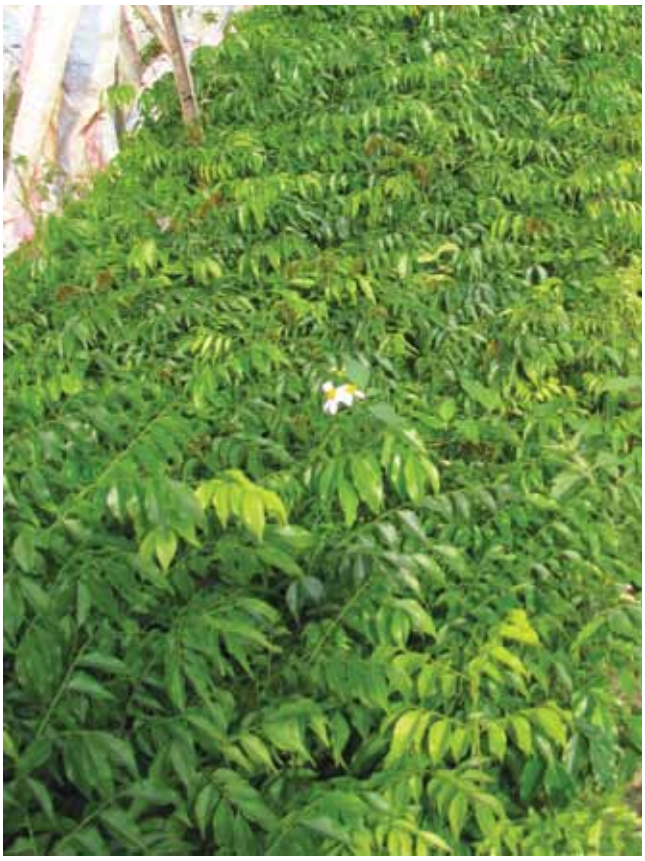

Figure 3. *Erythrophloeum fordii* seedlings in Phu Tho Province, Vietnam

Photo by Chaw Chaw Sein

Figure 4. Five-year-old *Erythrophloeum fordii* plantation in Phu Tho Province, Vietnam
Photo by Chaw Chaw Sein

days; if it is hot and dry, this should be increased to twice a day. Afterwards, they should be watered every 2–3 days. The amount of water depends on the weather, but it is vital to keep the pots damp (3–4 litres/m^2); excessive watering, however, could cause disease and should be avoided.

About every 15–20 days, the pots in which the seedlings are being stimulated should be combined and the 2-month-old seedlings should be classified; the seeds in the pots should be stimulated for growth for the last time 3–4 weeks before being planted out.

When the seedling growth is slow, top dressing should be applied. The first 3 months apply this dressing once a month: nitrogen/phosphorus/potassium (NPK) (5:10:3) at a concentration of 1% (0.1 kg/10 litres of water). Water the area with 3 litres/m^2. It is recommended to water the plants in the early morning or evening and then thoroughly wash the leaves with clean water (2.5 litres/m^2) to prevent disease (Duc 2004).

4.2 Preparation of planting site

Generally, increased tree growth and survival can be achieved through increased site cultivation. The degree of slope and level of soil compaction are the primary factors which influence the ability to conduct extensive site cultivation. Before cultivating, slashing or burning should be carried to reduce the existing vegetation as far as possible, in order to improve the ease of site access for heavy machinery and thereby effective soil cultivation.

Cultivation provides a better soil tilth for planting and can be achieved with a wide range of implements. Cultivation should be planned for a period when the soil is not too wet, avoiding soil compaction and damage to soil structure. Cultivation should be carried out well ahead of planting to allow the soil to settle.

One month before planting, holes measuring 40 × 40 × 40 cm should be dug, arranged in a quincunx pattern, in two corridors. The holes should be filled with soil and clean weeded at least 10–15 days before planting (Kha 2004).

4.3 Planting

The criteria for selecting seedlings to be planted out should be as follows: (1) seedlings should be 16–18 months old, green, well proportioned, pest-free, with best quality; (2) seedlings should be 40–50 cm in height and the diameter of root collar should be above 0.8 cm; (3) pots should be intact and seedlings should have many small, well developed roots (Duc 2004).

The planting operation itself should ideally be done in drizzle or on an overcast day. The planted holes should be banked up, without stones and weeds. If the plantation is to be established by direct sowing,

Table 1. Growth in diameter and height of *Erythrophloeum fordii* in 45 sample plots in Phu Tho Province, Vietnam (with age classes 2, 3, 5, 6, 13, 16 and 23 years)

Number of plots	Statistic	Number of trees/ha	Diameter (cm)	Height (m)	diameter increment (cm/year)	Height increment (m/year)
45	Minimum	573	0.6	1.2	0.5	0.5
45	Maximum	3437	18.8	14.8	1.4	1.4
45	Mean	1705	9.5	8.5	1.0	1.0
45	Standard deviation	773	7.0	5.1	0.2	0.3

3–4 seeds should be placed in each hole, which should then be covered with a soil layer 1.0–1.5 cm thick. When using seedlings, shade-giving trees should be maintained in the vegetative belts to assure 50% sunlight. *Erythrophloeum fordii* should be planted with varying spacing and with a maximum density of 1100 trees/ha, or 1600 trees/ha at most (Kha 2004).

5. Plantation maintenance

Early and sustained weed management and fertiliser treatment, and occasional watering in are all key elements in the successful establishment of a *Erythrophloeum fordii* plantation. The appropriate stocking rate (planting density) must be established in order to promote optimum growth rates and efficient plantation management.

5.1 Weeding

Weed control is necessary to reduce the competition for water and nutrients between trees and weeds. Competition from weeds severely decreases early tree performance, and weed growth can be prolific in subtropical and tropical regions. Weed control before planting and for at least 12 months after should be considered essential for successful plantation establishment. A weed-free strip 2 m wide should be established along each planting row during the first 2 years (Kha 2004).

Figure 5. Fourteen-year-old *Erythrophloeum fordii* plantation in Phu Tho Province, Vietnam

Photo by Chaw Chaw Sein

Table 2. Productivity of *Erythrophloeum fordii* in sample plots in Phu Tho Province, Vietnam

Number of plots	Statistic	Number of trees/ha	Stem volume (m^3/ha)	Volume increment (m^3/ha/yr)
45	Minimum	573	1.5	0.4
45	Maximum	3437	342.1	25.9
45	Mean	1705	93.5	6.3
45	Standard deviation	773	117.9	7.8

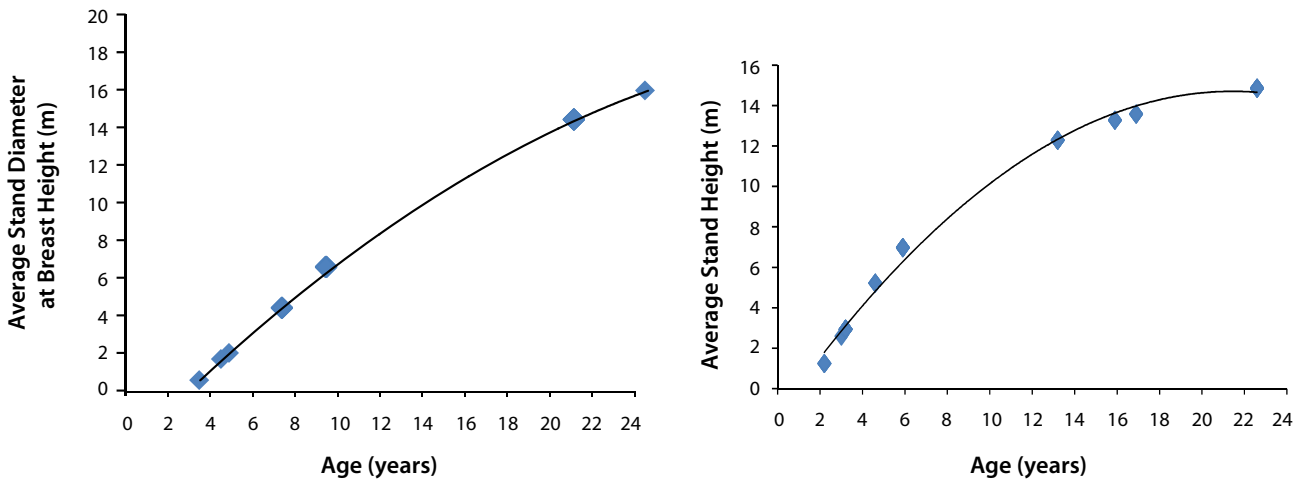

Figure 6. Growth in diameter and height of *Erythrophloeum fordii* in different age classes in sample plots in Phu Tho Province, Vietnam (Michailow's growth function)

5.2 Fertilising

Trees require nutrients to live and thrive: when a soil is nutrient poor, trees will not reach their full potential, will be more susceptible to disease and insect problems and will have a shorter lifespan than similar, well fertilised trees. Fertiliser products aimed at providing trees with the appropriate nutrients abound. Organic and inorganic fertilisers may be administered in a combination which allows nutrients to be delivered to a plant rapidly and for an extended period of time. Generally, fertiliser is applied at the time of planting and 6 months after planting. The most commonly use fertilisers are NPK and those based on micro-organisms. An indicator of the need for fertilisation is the history of the nursery. Trees in nurseries that are fertilised on a regular basis rarely need supplemental fertiliser on transplantation. Fertiliser is most effective when applied just prior to a good rainfall. The best fertiliser type for common soil environments is not yet established, nor is there an acceptable financial cost–benefit analysis for fertiliser application.

5.3 Refilling

The first refilling is usually done in the rainy season, 1 month after planting, to replace dead rooted cuttings or clonal plants, and the second is carried out at the end of the second year. If the survival rate is less than 70%, further replanting is necessary for large-scale plantations.

5.4 Pruning

The purpose of pruning is to encourage trees to develop a straight stem and more valuable, knot-free trunks. High-density plantations will have lower pruning costs than lower density plantations. The greater the initial distance in tree spacing, the more artificial pruning will be necessary to produce a clear bole. The closer the spacing of trees in a higher density plantation, the more they will be forced into an upright growth habit. The resultant lack of light will increase natural pruning of the lowest branches.

Pruning some branches increases the growth rate of the remaining branches (Ramos *et al.* 1998). In contrast, careless pruning can significantly reduce growth, introduce disease and reduce timber value. When the trees reach 2 years of age, pruning in late winter can encourage a single stem. Pruning should be done with great care in order to avoid damage to the branch collar and the branch bark bridge, which can lead to disease. Pruning tools should always be cleaned and sharpened to ensure a clean, smooth cut.

5.5 Thinning

Thinning is the selective process of removing some trees in order to afford the remaining trees the opportunity to maintain a steady growth rate. Poorly formed trees and species of lower value may also be selectively removed through thinning. If there is a lot of variation in growth and survival, thinning may be necessary only in areas where the trees are very thick. As one of the primary goals of thinning is to maintain steady growth, it is imperative that growth rates are monitored.

In tropical tree plantations, thinning is usually conducted from a relatively early stage of stand development (Lamprecht 1989, Evans and Turnbull 2004). Plantations need to be conscientiously managed to enhance stand quality and promote

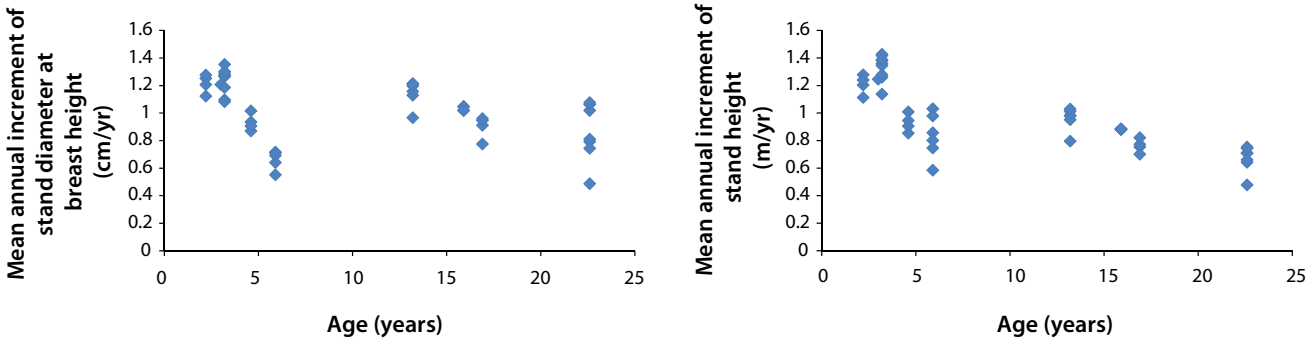

Figure 7. Average annual increase in diameter and height of *Erythrophloeum fordii* in different age classes in sample plots in Phu Tho Province, Vietnam

wood production. Tending operations such as thinning are typically used to increase production of usable-sized trees (Zeide 2001). Thinning can also provide an intermediate financial return from the removed trees (Evans and Turnbull 2004). Producing higher quality, large diameter timber usually requires at least one thinning (Lamprecht 1989). Regular thinning should be conducted when the plantation is 3, 5 and 7 years old.

6. Growth and yield

6.1 Growth in diameter and height

Erythrophloeum fordii samples were collected from 45 plots in smallholder plantations in Phu Tho Province, Vietnam, representing various age classes (2, 3, 5, 6, 13, 16 and 23 years). In this study, Michailow's growth function was used to estimate the diameter and height of the stand.

$$H = a * \exp\left(\frac{-b}{age}\right) \qquad D = a * \exp\left(\frac{-b}{age}\right)$$

Table 1 presents growth in diameter and height of samples from 45 *Erythrophloeum fordii* plots.

The annual growth in diameter and height from 1 to 23 years of age is nearly identical. These plantations were evaluated to determine the mean annual increases. They achieved a minimum increase in diameter of 0.6 cm and height of 1.2 m at 2 years of age and a maximum increase in diameter of 18.8 cm and height of 14.8 m at 23 years of age.

Figure 7 illustrates average annual increases in diameter and height with regard to age. The average annual increases in diameter of *Erythrophloeum fordii* are from 0.5 cm/year to 1.4 cm/year, with an average of 1.0 cm/year. The average annual increases in height are from 0.5 m/year to 1.4 m/year, with an average of 1.0 m/year for every variable.

6.2 Productivity

In order to estimate stand volume, single stem volume must be estimated first. To estimate stem volume for *Erythrophoeum fordii*, the data used previously for assessing the relationship between height and diameter were analysed. The total volume of each *Erythrophloeum fordii* sample tree was calculated using the following general model:

$$V = g \times h \times f$$

In this study, the rotation of *Erythrophloeum fordii* is 23 years. Chapman-Richards' generalisation of Bertalanffy's growth model (Richards 1959) was used to estimate stand volume:

$$V = a.[1 - \exp(-b.age)]^{c}$$

Table 2 presents productivity in 45 *Erythrophloeum fordii* sample plots.

The samples yielded minimum increases in volume of 1.5 m^3 at 2 years of age and 342.1 m^3 at 23 years of age, giving an average of 93.5 m^3/year increase in volume for these plantations.

Figure 8 illustrates the average annual increases in volume with regard to age. The average annual increases in volume of *Erythrophloeum fordii* are from 0.4 m^3/year to 25.9 m^3/year, with an average of 6.3 m^3/year for every variable.

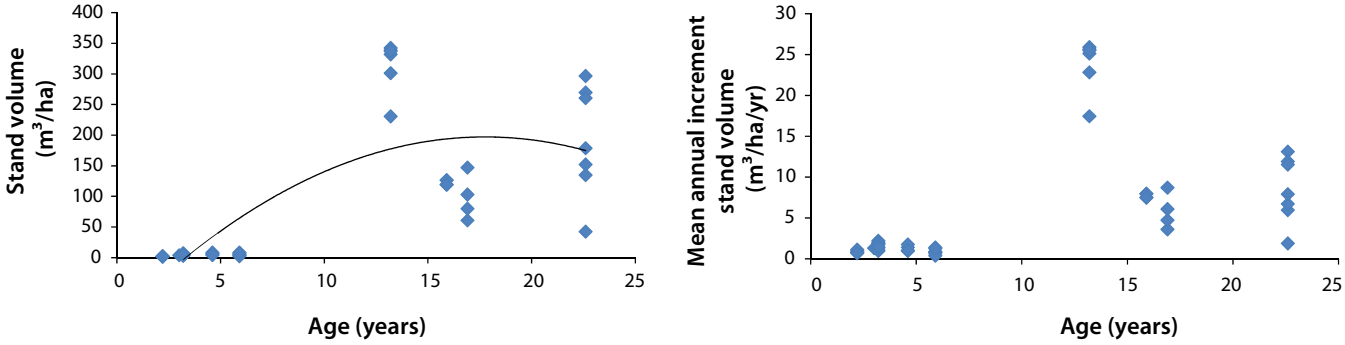

Figure 8. Average stand volume and average annual increase in volume of *Erythrophleum fordii* in different age classes in sample plots in Phu Tho Province, Vietnam

Table 3. *Erythrophloeum fordii* schedule of activity for smallholder plantations in Phu Tho Province, Vietnam

Year	Operations	Activities
E–1	1. Obtain seeds	From seed orchards, seed production areas and mother (plus) trees
	2. Raise plants in nursery	Bare rooted or container plants
	3. Prepare site	Slash and logging debris removed
		Holes excavated (40×40×40 cm)
E Planting	1. Spacing	Wide spacing used; mixed planting with other broad-leaved species is possible and results in higher productivity
	2. Planting system	Contour lines on slopes and straight lines on flat terrain. Plant at varying distances and in various densities ranging from 250 to 1100 trees/ha
	3. Fertilising	Fertiliser should be applied at planting time and 6 months later
E+1 Tending	1. Weeding	Weed control by manual weeding or herbicide application. Minimum of weeding twice a year during first 2 years of plantation growth is encouraged
	2. Refilling	2 months after planting for the first time; end of second year for the second time
E+2	Pruning	When the trees reach 2 years of age, pruning should be done carefully to avoid injury to the tree or damage to the branch collar
E+3	Thinning	Poorly formed trees and species of lower value should be selectively removed through thinning. Regular thinning is conducted when the plantation is 3, 5 and 7 years old
E+20 or more years,	Harvesting	The tree reaches the size or quality of timber which fetches a good price
		Native species have a long rotation period

E: Year of plantation establishment

6.3 Rotation

As it has a relatively long rotation of 20–25 years, the decision of when to harvest *Erythrophloeum fordii* ultimately depends on local markets and local climate conditions. Trees can be harvested earlier if threatened by drought, pests or disease, but are usually harvested when the trees reach the right size or quality to fetch a good price.

7. Schedule of activity

Table 3 presents a suggested schedule of operations and activities for smallholder plantations of *Erythrophloeum fordii* in Vietnam.

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This manual summarises information on the ecology and silviculture of the species *Erythrophloeum fordii* Oliver, with an emphasis on Vietnam. It also encompasses growth and yield data from published sources, as well as collected from sites under smallholder plantations in Phu Tho Province. This manual is 1 of 5 that guide smallholder tree planting of five selected tree species in Vietnam. The other four species are: *Acacia* hybrid, *Acacia mangium* Willd, *Cinnamomum parthenoxylon* (Jack) Meisn and *Eucalyptus urophylla* S.T. Blake.

Vietnam's environmental policy puts much emphasis on the objective of restoring forest ecosystems, protecting ecological environments and conserving biodiversity, in particular indigenous species. The Government of Vietnam is currently carrying out a large scale 'reforestation' programme, with the aim of improving local livelihood security, environmental sustainability and industrial wood supply. Smallholders are involved in plantation timber production through various schemes. Generally, these efforts have been effective, even though smallholders often lack the appropriate technical knowledge and management skills. Consequently, the quality and quantity of products may be suboptimal. The productivity of smallholder plantations can be improved by enhancing smallholders' management knowledge and skills, including species selection (site matching), silvicultural management to produce high quality products, and pest and disease management.

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