Silviculture and productivity of five economically important timber species of central terai of Nepal

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Cover photo (front): *Gmelina arborea*

Cover photo (back above): *Tectona grandis*

Cover photo (back below): *Anthocephalus chinensis*

Photo Credit: Nepal Agroforestry Foundation (NAF), Terai Private Forest Development Association (TPFDA), Internet, and Author.

"*(...) forestry is not, in its essence, about trees. It is about people. It is about trees only so far as they can serve the needs of people*"
-Jack Westoby

Foreword

People of Nepal are heavily dependent on forests for the supply of fuel wood, fodder and timber. The annual estimated consumption of traditional fuel is 11.3 million m^3 of which dung and farm residues supply 28% in the *terai* and 18% in the hills. Of the total fuel-wood supply, 14 % in the *terai* and 33% in the hills is obtained from private wood lots.

Overall, in Nepal 80% of domestic and industrial energy consumption is supplied through fuel-wood, largely from natural forest, which is being depleted at an increasing and unsustainable manner. The deforestation rate in the *terai* is higher than in the mountain due to increased population and fast growing timber market. The high demand of fuel-wood and timber including non-timber forest products has accelerated rate of deforestation in Nepal, which resulted in severe forest degradation in the country. The *Churia* hills and *Bhawar* region of the central *terai* are considered fragile ecosystems and are at the verge of land degradation. Some initiatives have been taken in the past by some development program to combat land degradation. These initiatives include distribution of improved cooking stove, bio-gas plant establishment, briquette production, use of solar energy and agroforestry-based private forestry.

In the recent past private forestry has become a recognized practice in the central *terai*, especially in *Dhanusha* district when Nepal Agroforestry Foundation (NAF) intervened an agroforestry based private forestry in its project area supported by the Danish Forestry Extension (DFE). NAF has promoted five timber species namely *Dalbergia sissoo, Eucalyptus camaldulensis, Gmelina arborea, Anthocephalus chinensis* and *Tectona grandis* in the area. However, the technical-know -how and other required skills of tree growers on these species is still limited and confined to only seedling plantation, weeding and final harvesting without considering the economic return. Private forestry is not just these few activities but covers a large array of activities from seed collection to final harvesting. This is the reason why the private tree growers in the *terai* are bereft of getting a reasonable return from their investment. No doubt, private forestry has been a successful intervention because agriculture and even vegetable farming is no more a profitable business in the area but still there exists a bigger gap in knowledge of local private tree growers on silviculture of these species. Besides, local change agents including District Forest Office (DFO) and various Non-governmental Organizations (NGOs) are not updated on recent silvicultural technologies to teach local farmers. It can be said that these knowledge gaps have somehow hindered the sustainable management of private forestry.

In this back drop, this book entitled **"Silviculture and productivity of five economically important timber species of central terai of Nepal"** will be useful for the farmers of Nepal, particularly the *terai* region and for the forestry professionals to promote private forestry program both in *terai* and hills of Nepal. So far as I know, this is the first ever published book that deals with required knowledge and skill of silvicultural practices of the selected species, which would be a valuable resource for people of Nepal who are seeking to develop private forestry on their farmlands.

Bishnu Hari Pandit, PhD
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Preface

Putting in view the problems facing the private tree growers with silviculture of timber species in the central terai of Nepal, the author has attempted to develop this book entitled **"Silviculture and productivity of five economically important timber species of central terai of Nepal".** The sole objective of this book is to disseminate the technical-know-how (how to promote private forest) of five economically important timber tree species to the wider community of Nepal, who are interested in growing private forestry. These five species include *Dalbergia sissoo, Eucalyptus camaldulensis, Anthocephalus chinensis, Gmelina arborea*, and *Tectona grandis*. These species have been chosen by the author from among the timber species suitable for the central terai region because they are the most preferred species by the tree growers. Author believes that this book will prove to be a reliable handbook for the extension workers, forestry officials and other people who are involved in forestry sector.

In this book I will discuss major three aspects of raising trees on the farm: silviculture of the species, growth performance of the species and economics and trade of the species. The first component is largely based on available literatures and partly on field observation and interaction with tree growers and the rest two are based on the study carried out by the author himself. The silviculture component covers mainly geographic distribution, silvicultural characteristics, morphology, phenology, nursery techniques, plantation techniques and uses. The second component covers the growth pattern between two modes of plantation: bund and stand. The third component covers existing marketing channels of timber, market price scenario of timber over time and benefit-cost analysis of timber/pole production.

The book would not shape into this present form without support from the International Tropical Timber Organization (ITTO), Japan. Therefore, author would like to take this opportunity to express a sincere gratitude to the ITTO for providing the fellowship to carry out this work. Author is also indebted to the host institution, the Nepal Agroforestry Foundation (NAF) for providing relevant literature and supporting at the time of data collection. The entire staffs of the Terai Private Forest Development Association (TPDFA), *Dhanusha* are highly acknowledged for their support while collecting data.

Further, there are many names that the author will always remain indebted to for their contribution to this book. Firstly, author would like to extend his sincere thanks to Dr. Bishnu Hari Pandit, principal of Kathmandu Forestry College (KAFCOL) for his technical advice for the improvement of the book. Similarly, thanks are due to Mr. Buddi Sagar Paudel, Wildlife officer, Mr. Shree Krishna Gautam, Forest officer and Mr. Hari Sharan Luintel, Coordinator of Forest Action for their valuable suggestions and comments.

Author

Acronyms and Abbreviations

Avg.	: Average
B/C	: Benefit Cost ratio
BA	: Basal Area
C	: Circumference
CAI	: Current Annual Increment
Cft	: Cubic feet
DBH	: Diameter at Breast Height
DFO	: District Forest Office
Dia.	: Diameter
DoF	: Department of Forest
H/D	: Height to Diameter ratio
Ha	: Hectare
Ht	: Height
MAI	: Mean Annual Increment
Max.	: Maximum
NAF	: Nepal Agroforestry Foundation (NAF)
NGO	: Non-governmental Organization
NPK	: Nitrogen, Phosphorus and Potassium
NPV	: Net Present Value
PV	: Present Value
S/B	: Stand to Bund ratio
TCPF	: Terai Community Forestry Project
TPFDA	: Terai Private Forest Development Association
VDC	: Village Development Committee

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DALBERGIA SISSOO

Indian Rosewood
(Fabaceae)
Sissoo

A. Silviculture

1. Scientific classification

Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Fabales
Family:	Fabaceae
Subfamily:	Faboideae
Genus:	Dalbergia
Scientific Name:	*Dalbergia sissoo* Roxb. ex DC.
Local name:	*Shisham, Sisau, Sissoo*
English Name:	Indian Rosewood

2. General introduction

One of the most preferred private forestry species in the past in the terai region of Nepal, *D. sissoo* is an erect deciduous tree. It is also called *Shisham, Sisu, Sissoo* and Indian Rosewood. It is primarily found growing along river banks below 900 m elevation, but can range naturally up to 1300 m.

D. sissoo is best known internationally as a premier timber species of the rosewood genus. However, it is also an important fuel wood, shade and shelter. With its multiple products and tolerant of light frosts and long dry seasons, this species deserves greater consideration for tree farming, reforestation and agro-forestry applications.

D. sissoo is a multipurpose tree and produces nitrogen-rich fodder and green manures, high quality fuel-wood and charcoal, strong and durable poles, and beautiful dark brown wood for furniture and paneling. It is also used in agroforestry system to protect soil, improve crop production (due to nitrogen fixation) and provide long-term financial security. These characteristics make *D. sissoo* a popular species for afforestation, industrial plantations and farm forestry planting. It is a valuable resource for national forestry program, commercial enterprises and private farmers.

3. Geographic distribution

Sissoo is native to Pakistan, Oman, Bhutan, India, Nepal, Myanmar and exotic to United States (Florida, Arizona), Puerto Rico, Costa Rica, Cyprus, Benin, Cameroon, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Nigeria, Senegal, South Africa, Sudan, Tanzania, Togo, Zimbabwe, French Polynesia, New Caledonia, Australia, Indonesia, Thailand, Sri Lanka, Taiwan, Israel.

4. Historical background of *Sissoo* plantation

D. sissoo is currently one of the most frequently planted trees in Nepal and has a long history of plantation establishment in the country. More than 40% of all forest trees planted in Nepal and more than 90% of all trees planted in the flat "Terai" region of Nepal are *D. sissoo*. However, many plantations have been seriously affected by a die-back disease of unknown cause in the recent past, and phenotypic characteristics such as stem form and branching habit are often inferior in plantations. The history of tree plantation in Nepal started with the plantation of *Pinus roxburghii* in and around

Kathmandu valley in the early 1950s. The large scale plantation of *D. sissoo* in the lowlands (*Terai* and inner *Terai*), however, began only in the mid 1970s. Various organizations such as the district level forestry offices of the Department of Forest (DoF), the Terai Community Forestry Project (TCFP), the *Sagarnath*, *Ratuamai* and *Nepalgung* Forestry Development Projects, etc. were involved in the plantations in the lowland. With the growing awareness of tree plantations coupled with the decreasing supply of fuel-wood and timber form public forests, a large number of private entrepreneurs also started planting S*issoo* in private lands. The plantations were also set up in degraded public forestland, canal-sides, and roadsides, on crop fields and on marginal lands. The occurrence of the species in natural forests in Nepal is restricted to a few fragmented relics of autochthonous populations.

5. Morphology

D. sissoo is a medium to large deciduous tree with a light crown which reproduces by seeds and suckers. It can grow up to a maximum of 25 m in height and 2 to 3 m in diameter, but is usually smaller. Trunks are often crooked when grown in the open.

Stems

Young shoots are downy and drooping and established stems have light brown to dark gray bark to 2.5 cm thick. Large upper branches support a spreading crown.

Leaves

Leaves are leathery, pubescent when young, glabrous later; alternate, pinnately compound and about 15 cm long, comprising 3 to 7 leaflets with pinnate venation, broadly elliptical to ovate, tapering to a point and 2.5-3.6 cm in diameter.

Flowers

Flowers are bisexual, small, whitish to pink, fragrant, nearly sessile, up to 1.5 cm long and in dense clusters 5-10 cm in length.

Seeds/pods

Pods are brown, flat and almost oblong. They are 5 to 7.5 cm long, 1 cm wide, strap-shaped, pale-brown, glabrous, indehiscent, 1 to 4 seeded (Figure 1). Seeds are 6-8 mm by 4-5 mm in size; kidney shaped, thin, flat, light brown with a papery testa. Pods hang in dense clusters at the ends of the shoots. There are 40000-55000 seeds per kg. Seed production starts when the trees are 3-4 years old and normally a good crop is produced every year with yields of 1-3 kg per tree.

Root

A long taproot and numerous surface roots which produce suckers.

Twigs

Current year twig color: brown; green
Current year twig thickness: medium; thin

Bark

Bark is thin and easily damaged from mechanical impact; droops as the tree grows. It is coarse and gray in color.

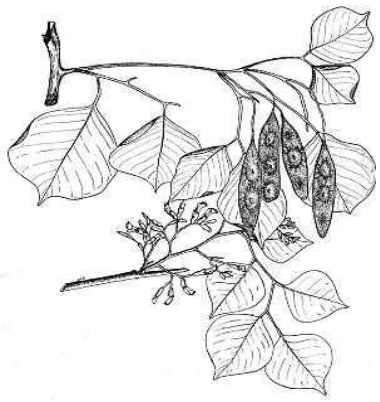


Figure 1: *Sissoo* pods

6. Phenology

Reproduction ecology

D. sissoo produces flowers profusely. The small bisexual flowers are borne on small branches from the leaf axis. Flowering closely follows leaf flushing; leaves fall and young flower buds appear with new leaves followed by complete pod formation and maturity. Mature pods remain attached to the tree for 7-8 months and are then dispersed by wind and water.

Leaves abscission

Within the area of natural distribution the leaves are shed in November-December and new leaves appear in January-February.

Blooming season

White flowers in short panicles appear in March to April. By the end of April, young green pods appear and in October when the dry season sets in, the fruits begin to ripen.

Pollination ecology

Little is known of pollination biology and breeding system. The species appears to be insect pollinated and trees can apparently be both self- and out-crossing to varying degrees, depending on local conditions.

Although results have been conflicting, the most recent results point to the species being partial selfing and partial out-crossing, a type of breeding system often found in pioneer species. The rate of out-crossing has been estimated to 60-90%, it varies between populations and for the single population over time.

Fruiting Season

Although fruits are formed early, they mature in December to January.

Seed dispersal ecology

By wind or water

Seed viability

Pods are collected from December to March. Pods are dried in the sun for 3 to 4 days. Well dried and moisture protected pods may be kept for 3 years without much loss in viability. The mature pods are persistent on the tree for 7-8 months. However, seed remains viable for a few months once exposed to air.

Propagation Ecology

By seeds and suckers

New plants are propagated from seeds and root suckers. The roots are *dimorphous*, comprising nutrition roots without buds which penetrate downwards into the soil and long horizontal roots with buds, from which suckers are produced.

By cuttings

D. sissoo can be reproduced by cuttings too. The cuttings should be from one year old branches of *Sissoo* with 15-20 year age having 35-40 cm diameter. These cuttings are collected in the months of January and February. The cuttings should be 23 cm long with a thickness of 10 mm. The cuttings are treated with bleach with 1:4 ratios for ½ hour to disinfect them from any pest/pathogen infestation. Then the well treated cuttings are inoculated in polythene bags (23cm x 10cm) filled with silt as a rooting medium (figure 2). The controlled conditions of temperature (about 30-40˚ C) and humidity (about 70-80 %) are maintained by covering the cuttings with polythene sheet during root development. Watering is carried out as and when required to avoid any fungal growth. Weeding is also done during this period.

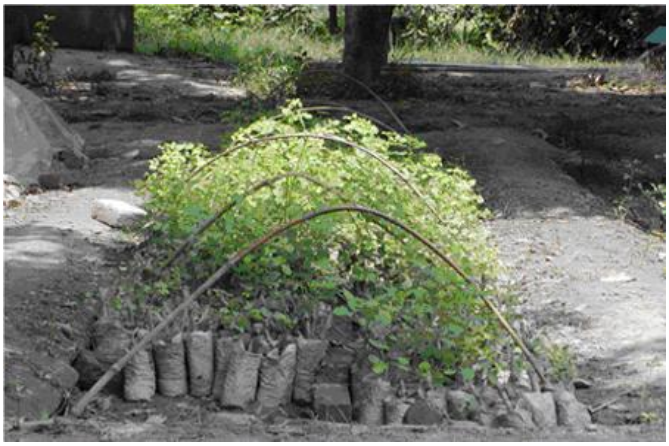


Figure 2: Vegetative nursery

7. Habitat/ecology

Growth is most prolific in tropical and sub-tropical climates (up to 1000m), particularly in areas where there is considerable soil moisture (but not waterlogged soils). Recommended for plantations on sandy and gravelly alluvium soils on beds of river, it avoids stiff clay, preferring porous soil of sand, pebbles and boulders. It is identified by somewhat crooked bole acuminate leaves. It does not tolerate heavy clays, shallow soils or water-logging. It is sensitive to fire and even light fires will damage the trees. The natural populations of *D. sissoo* have been selectively logged for several hundred years which has led to a seriously depleted gene pool. It tolerates temperatures from below 0°C to nearly 50°C. In its natural range the annual rainfall varies from 750 to 4500 mm concentrated in 4-5 months followed by dry season. It can survive with only 400 mm rain/year but best growth is achieved with 1000-1700 mm rain. The temperature in its native range averages 10-40 °C. It can withstand average annual rainfall up to 2000 mm and droughts of 3-4 months.

Soil pH requirements
5.6 to 6.0 (acidic)
6.1 to 6.5 (mildly acidic)
6.6 to 7.5 (neutral)

8. Patterns of plantation

Pattern

In case of *D. sissoo,* farmers prefer both the bund and stand plantation depending upon the availability of the land and labor. The bund plantation requires no land specially allocated as seedlings are planted along the bund of the cultivated field. The cost of establishment is lower in case of the bund as compared to the stand. Bund cultivation requires less effort in preparing field and hence requires minimum number of labors. One obvious benefit of the bund plantation to the plants is that they can use the manure and fertilizer applied in the field for the major crops. In the recent past, due to the problem of death being higher in *Sissoo* crop, farmers are reluctant to raise this species anymore. That might be the reason why there is not any plantation of younger age (below 5 years) in the central *terai*.

Spacing

It's a common practice that farmers prefer to have a one meter gap in case of bund plantation i.e. 101 seedlings in a 100 meter long bund while in case of stand, three different spacing systems are in practice i.e. 4*4 m^2 , 2*2 m^2, 3*3 m^2. Spacing varies with objectives of the plantation. When objective is to produce fuel-wood, narrow spacing is preferred to the wider one. For timber, obviously the preferred spacing would be the wider one.

9. Nursery techniques

Seed collection

Ripe fruits can be harvested from December to March. The fruits should be collected from the tree by climbing or by shaking the fruits onto a tarpaulin on the ground. It is not advisable to collect from the ground as the seeds are often infected. 1.25 kg pods contain about 1 kg seed.

Processing and handling

After collection the pods are dried in the sun and when dry, they are broken in segments each containing one seed. The segments are then cleaned by winnowing to remove empty pieces of pods.

Storage and viability

The seeds are orthodox and when properly dried and stored in airtight containers they will retain high viability for several years even at room temperature, longer if stored at 5°C. The seeds can be infested by the pea beetle, *Bruchus pisorum*. Infestation is initiated in the field but breeding can continue during storage.

Seed Biology

No. of pods per kg.	No. of seeds per Kg.	Germination percentage	Germination period in days
16,000 to 18,000	40,000 to 55,000	90 to 100	8 to 20

Pretreatment

The seeds are not hard coated and scarification is not necessary. Soaking for 24-48 hours in cold water before sowing improves germination and 60-80% germination can be expected in 1-3 weeks. Seeds germinate better if planted when still within the pod. Seedlings are raised in the partial sun or full sun. Seeds are sown in beds or in poly-pots in March-April. Seedlings are ready for plantation after six months in nursery. Plantation is commonly carried out in the rainy season (June-July) in Nepal.

Sowing and germination

The ploughed soil can be organized into beds of 1 meter wide, 15 cm high, 10 meters long, or as long as the topography would allow and then seeds (pod segments) are sown in March-April in lines in raised seed-beds and watered two times every day. Sowing seeds in the prepared beds is carried out in march-April. Germination starts after about one week and is completed in about three weeks. The germination rate is typically 60-80%. When the seedlings are about 5 cm tall, they are transplanted into containers. For production of stumps, 12-16 months are required in the nursery.

Seed sowing in the poly bags

Seeds can be raised in poly-pots directly. Broken pieces of pods, each containing one seed are sown in each poly pot. Too much watering is avoided. Roots coming out of the poly pot are necessary to prune regularly as seedlings develop strong taproots. Transplanting is another method of raising seedlings in poly-bags. When seedlings are 2-3 cm tall and have developed two pairs of leaves in the nursery beds, they can be transplanted in the already prepared poly-pots.

10. Establishment of plantation

Site preparation

Site preparation should be carried out in February-March by plowing and digging of planting holes. A firebreak is made with 4–6 m wide strips by plowing, digging and controlled burning. Fencing is required to protect the seedlings against cattle.

Planting out

The time of planting is June or July. Stump cuttings are commonly used for establishment. Plants are grown for 6 months to 1 year in beds, pulled up carefully and cut to leave 5- 10 cm of stem and 20-25 cm of root. Stumps thicker than 2.5 cm and thinner than 1.5 cm in diameter are rejected in Pakistan, although in Nepal stumps average 1 cm in diameter at the root collar. Container-grown seedlings also are used, but out-planting survival averages only 50%.

Container-grown seedlings also are used, but out-planting survival averages only 50%. Direct seeding has been a common practice in *Taungya* plantings in India. Rows are planted 3 m apart and saplings are thinned to 1 m spacing within rows after one year. It is also possible to raise plants from stem cuttings. The age of the tree and time of planting are very important. Rooting success of hardwood cuttings from 1-year-old and 4-year-old trees ranges from 34-73% and 18-38% respectively.

Weeding

Thorough weeding is important during the first 2-3 years.

Irrigation

Irrigation is very important for establishment of S*issoo.* Even semiarid areas, irrigation is necessary. *Sissoo* should be able to tap sub-soil water within a couple of years if irrigated properly.

Fertilizer application

Fertilization with various combinations and amounts of NPK shows no significant effects on DBH or height over 5-6 years on a rich soil. Phosphate would normally be expected to promote early growth on poor soils.

Disease and pest

Pests reported include *Plecoptera reflexa* (a defoliator), *Dichomeris eridans* (leaf binder), *Brachytrypes portentosus* (causing nursery damage) and termites that attack young trees. Parasitic plants reported to cause considerable damage to *sissoo* include *Loranthus longiflorus* and *Tapinenthus dodoneifolius*; in alluvial forests, climbers like *Dregea volobilis*, *Cryptolepis buchanani* and *Acacia pennata* cause the same damage. Leaf diseases include the powdery mildew fungus, *Cercospora sissoo* (leaf spot), *Colletotrichum sissoo* (leaf blight fungus), and *Fusarium solani dalbergiae* (leaf wilt). Wood pathogens recorded include *Daedalea flavida* (wood rot fungus) and *Fomes durissimus* (stump rot fungus). The fungus, *Ganoderma lucidum*, which causes root and butt rot, is common. *Sissoo* suffers minor damage from two foliage rusts and a powdery mildew.

11. Intercropping

Intercropping wheat, cow pea, lentil, and banana in the *D. sissoo* stand is a common practice in Nepal. Studies done so far betokens that the intercropping practice has a positive impact on soil organic matter, microbial biomass C, basal respiration and dehydrogenase and alkaline phosphatase activities. Adoption of the agro-forestry practices had led to an improved organic matter status of the soil. However, tree spacing should be properly maintained to minimize the effects of shading on the intercrops.

12. Uses

D. sissoo is one of the most useful multipurpose trees of South Asia. It is mainly grown for the timber which is among the finest for cabinets, furniture and veneer. The heartwood is golden to dark brown with density of 0.7-0.8 g/cm3 (at 12% mc) extremely durable and resistant to termites. Major uses are summarized below.

Timber

D. sissoo is among the finest cabinet, furniture and veneer timbers. The heartwood is golden to dark brown, and sapwood white to pale brownish white. The heartwood is extremely durable (Specific Gravity = 0.7- 0.8), and is very resistant to dry-wood termites; but the sapwood is readily attacked by fungi and borers. It is used for plywood, agricultural, and musical instruments, skis, carvings, boats, floorings, etc.

Fuel-wood

The calorific value of the sapwood and heartwood of 'excellent' fuel wood is reported to be 4908 kcal/kg and 5181 kcal/kg, respectively. As a fuel-wood it is grown on a 10 to 15-year rotation. The tree has excellent coppicing ability, although a loss of vigor after two or three rotations has been reported. *Sissoo* wood makes excellent charcoal for heating and cooking.

Fodder

Leaves, young shoots and green pods are an important source of fodder. The leaves contain up to 24% crude protein (dry weight basis) and dry matter digestibility is about 56%. The fodder value is highest in April and May when other sources of green fodder are scarce.

Other uses

The species is nitrogen fixing and used in agro-forestry systems with many crops. Although S*issoo* trees can negatively affect crop production due to competition for nutrients, moisture and light, studies have shown that the net value of intercropping S*issoo* and wheat is higher than wheat Mono-cropping. It provides shade and shelter and is used as such in mango, tea and coffee plantations. Its habit of developing root suckers and runners makes it useful for erosion control. In the U.S., it is said to be one of the most desirable shade trees for streets and backyards. Apart from the above, S*issoo* provides other minor products (e.g. honey) of high economic importance.

The ease of propagation by self-seeding, coppice, root suckers and stumps and the many environmental and socio-economic benefits makes it one of the most valued tree species by farmers in the central terai of Nepal. The tree has many reputed medicinal properties and has been used

culturally for a variety of ailments including: skin diseases, blood diseases, syphilis, stomach problems, dysentry, nausea, eye and nose disorders, aphrodisiac, expectorant, among others.

B. Growth performance

1. Study design and methods

1.1 Study area description

Data presented in the book were collected from the central development region of Nepal, *Dhanusha* district, the project area of Nepal Agroforestry Foundation (NAF), where NAF has been working for 15 years for promoting private forestry in the district. The study covered nine VDCs of the district, where farmers have established stands of *Sissoo* of different age ranging from year 5 to 15 years old. The geography of the area is very fragile and soil is sandy and hence the water holding capacity of the area is very low.

1.2 Sample size and sampling intensity

Stands with at least 5 *Kathas* (30 *Kathas* = 1 hectare) were taken into consideration for the study. Two major variables were measured: Diameter at Breast Height (DBH) and Height. Data were collected from the stands aged 5, 10 and 15. There were altogether 9 stands measured (3 replications). Site quality has been assumed to be the same in each stand. Since the stands are from the same source i.e. NAF's nursery, author assumes that the stand performs the similar growth pattern. The sampling size (unit) was 5*5 m^2 with 2 % sampling intensity. The sampling units were randomly selected. Based on the data from the sample plots, Current Annual Increment (CAI) was calculated and a table was developed which gives the possible DBH and height for each age from 5 to 15. For the calculation of CAI of the stand above 15 years, authors collected data from the reliable literatures.

In case of bund plantation, individual tree was considered as sampling unit and the first one was selected randomly and rest was selected systematically i.e. every third tree. Therefore, the method selected for the bund was systematic sampling with random start.

2. Findings

2.1 Growth performance in the bund and the stand (Based on average diameter)

The average diameter of the 20 years old plantation is 24.7 cm and 29.1 cm in stand and bund respectively. Even though the average growth of the two plantation patterns does not vary, the initial growth being higher in case of the bund plantation, the bund crop reaches the size 24.7 cm in 11 years, assuming the constant rate of growth over time within a class interval (Table 1). The growth rate varies with the plantation pattern. The growth is fluctuating in the stand but in the bund constantly decreasing over time, thus making yield prediction much easier than that of the stand. The Mean Annual Increment (MAI) is higher in the bund than in the stand. The stand to bund growth ratio (S/B ratio) is higher in the initial age and gradually decreases at middle and again increases gradually

after 15 years, indicating that the growth pattern in the initial and later age is very much close to each other and having a great difference at the middle (Table 1).

Table 1: Growth pattern over time in DBH (cm)

Pattern	Age (Years)																
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MAI
Stand	9.8	10.9	11.9	13.0	14.0	15.1	15.6	16.0	16.5	16.9	17.4	18.9	20.3	21.8	23.3	24.7	1.23
Bund	11.9	14.2	16.6	19.0	21.4	23.7	24.5	25.3	26.1	26.8	27.6	27.9	28.2	28.5	28.8	29.1	1.46
Ratio	0.82	0.76	0.72	0.68	0.66	0.64	0.63	0.63	0.63	0.63	0.63	0.67	0.72	0.76	0.81	0.85	0.84

Source: Fiend Survey, 2007

2.2 Growth performance in the bund and the stand (Based on maximum diameter)

In the initial age until 6, the growth pattern differs slightly in these two modes of plantation. After six until 13**,** the growth pattern changes abruptly, making a difference of about 8 cm at the age of 10. Highest difference is seen at the age of 10. Assuming the constant increase in growth within each age class, the following growth has been projected for every single age within each class. The 35.6 cm size is achieved in 15 years i.e. 5 years prior to the stand crops. The MAI is obviously higher in the bund than in the stand The Stand to bund growth ratio (S/B ratio) is higher in the initial age and gradually decreases at middle and again increases gradually after 13 years, indicating that the growth pattern in the initial and later age is very much close to each other and having a bigger difference at the middle (Table 2).

Table 2: Growth pattern over time in DBH (cm)

Pattern	Age (Years)																
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	MAI
Stand	14.5	15.3	16.1	16.9	17.7	18.6	21.3	24.1	26.9	29.6	32.4	33	33.6	34.3	35	35.6	1.78
Bund	15.4	18.7	22.1	25.4	28.8	32.2	32.8	33.5	34.2	34.9	35.6	36.1	36.6	37.1	37.6	38.1	1.90
Ratio	0.94	0.82	0.73	0.67	0.62	0.58	0.65	0.72	0.79	0.85	0.91	0.92	0.92	0.93	0.93	0.93	0.93

Source: Fiend Survey, 2007

2.3 Productivity of the stand and bund (Based on the average diameter)

The ratio of productivity between the bund (in meter) and the stand (hectare) indicates that the difference in productivity decreases until 15 years. With some increase for a few years after 15, the B/S ratio again starts decreasing until 20. To achieve 80 m^2 BA in 20 years, about 80/6.72 (12) bunds of 100 meter long is required. Hence, a 1200 meter long bund produces the Basal Area (BA) equal to the one hectare stand of 20 years (Table 3).

Table 3: Productivity of a stand and a bund in terms of basal area (m^2)

Pattern		**Age (years)**															
	Parameters	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	14	15	16	17	18	19	20
Bund (B)	**BA/tree**	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07
	BA/100m	1.13	1.62	2.20	2.87	3.63	4.48	4.78	5.09	5.41	5.73	6.07	6.20	6.33	6.46	6.59	6.72
Stand (S)	**BA/tree**	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05
	BA/Ha	12.6	15.4	18.6	22.1	25.8	29.9	31.7	33.6	35.5	37.5	39.5	46.5	54.0	62.1	70.8	80.0
	Ratio B/S	0.09	0.10	0.12	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.13	0.12	0.10	0.09	0.08

Source: Field Survey, 2007

C. Economics and trade

1. Introduction

The general mode of trade for timber, poles and fuel-wood is basically contractor-based in the central *terai* of Nepal. The local contractors collect wood (timber and poles especially) from the private tree growers and sells them either in the local market i.e. saw mill owners or directly transport to the big city centers like *Kathmandu*, *Pokhara* and *Narayanghat* and *Janakpurdham*. Besides, some farmer-led organization has also taken initiatives for marketing and trade of their forest products. For example, the Terai Private Forest Development Association (TPFDA) in *Dhanusha* district, which is supported by Nepal Agroforestry Foundation (NAF), is engaged in timber and pole marketing to avoid the contractor-based marketing channel for the benefits of private tree growers.

2. Methods of market study

This study only covered the local level market of the timber. For this, author had selected only five saw mills out of 20 currently running within the project area. The purpose of saw mill survey was to find out the size of timber in demand in local market and trend of price of timber over time according to its size. The price of the species for each size from 2002 to 2007 has been collected and presented in the table 4.

3. Market value

Even though *Sissoo* is one of the most preferred species for timber and fuel-wood, due to the heavy destruction by disease infection, the supply of *Sissoo* timber has been drastically decreased in the recent past. *Sissoo* is not preferred for plywood. The local level contractors buy the products from farmers and sell them either in the local sawmills or in Kathmandu.

4. Marketable size

The preferred size by the local saw mills runners varies from 2 ft to 5 ft in girth and the price is fixed accordingly. The minimum length fixed for a log is 6ft (Table 4). If any log smaller than 6 ft, that is not considered suitable for producing the desired size of timber for furniture. Therefore the rate for such timber will be fixed randomly by the sawmill owners.

5. Market price scenario over time

In the last six years, there has been a change in market price of *D. Sissoo* wood in every size. The rate of growth in price is higher in smaller size timber than in the bigger ones (Table 4). Therefore, in long run, producing small size timber is far better from financial point of view.

Table 4: Market price of the *Sissoo* wood in local sawmills

Dimension								Year-wise price/c ft (2002 to 2007)							
Girth (ft)	DBH (ft)	DBH (inch)	DBH (cm)	<, >	L(ft)	Volume	Rate/Cft	02	03	04	05	06	07	Increase in price (%)	Total Price
2 (I)	0.6	7.6	19.4	<	6	1.91	150	60	60	60	80	150	150	20.2	286.62
2 (II)	0.6	7.6	19.4	>	6	1.91	200	95	95	125	125	200	200	16.1	382.17

4 (III)	1.3	15.3	38.8	<	6	7.64	310	175	175	210	250	310	310	12.12	2369.43
4 (IV)	1.3	15.3	38.8	>	6	7.64	425	200	200	240	325	425	425	16.3	3248.41
5 (V)	1.6	19.1	48.5	<	6	11.94	425								5075.64
5	1.6	19.1	48.5	>	6	11.94	500	300	300	350	350	450	500	10.8	5971.34

Source: Field Survey, 2007

6. B/C ratio and rotation period

The marketable size at the local market is given in the table 4. Basically two sizes (Size II and Size IV) are more dominant. Therefore B/C for the two size classes has been carried out (Table 6). Based on the maximum diameter attained by S*issoo* at every single age from 5 to 20, MAI has been calculated (Table 5). The size II and IV are attained at the age of 10 and 20 respectively. Based on the need of the farmers and land availability, two rotations are recommended i.e. 10 and 20 years. We can make two harvests if we follow the 10 years rotation. Now what we need to assess is if it is more beneficial in terms of income to have a 10 year rotation rather than 20. Total income has been calculated based on the total marketable height and volume of that height (Table 5).

Table 5: Year-wise productivity of the *Sissoo* stand

Age	Avg. Dia. (cm)	Avg. ht. (m)	H/D ratio	Max. Dia. (cm)	Max. Height (m)	H/D ratio	Marketable length(m)		Avg. log Volume (m^3)		Total Volume/ha		MAI
							Avg.	Max.	Avg.	Max.	Avg.	Max.	
5	9.8	9	0.92	14.5	9.6	0.66	6.0	6.4		0.106		176.7	35.3
6	10.9	10.9	1.00	15.32	13.3	0.87	7.3	8.9		0.140		233.4	38.9
7	11.9	11.6	0.97	16.14	14.9	0.92	7.7	9.9		0.209		348.4	49.8
8	13	12.3	0.95	16.96	16.7	0.98	8.2	11.1		0.224		373.4	46.7
9	14	13.1	0.93	17.78	18.6	1.05	8.7	12.4		0.285		475.1	52.8
10	15.1	13.9	0.92	18.6	20.9	1.12	9.2	13.9		0.362		603.5	60.3
11	15.6	14.1	0.91	21.36	21.7	1.02	9.4	14.5		0.428		713.5	64.9
12	16	14.4	0.9	24.12	22.6	0.94	9.6	15.1		0.677		1128.6	94.0
13	16.5	14.7	0.89	26.88	23.5	0.88	9.8	15.7		0.838		1396.9	107.5
14	16.9	15.0	0.89	29.64	24.5	0.83	10.0	16.3		1.080		1800.4	128.6
15	17.4	15.3	0.88	32.4	25.5	0.79	10.2	17.0		1.380		2300.5	153.4
16	18.9	15.6	0.83	33.04	26.1	0.79	10.4	17.4		1.440		2400.5	150.0
17	20.3	15.9	0.78	33.68	26.6	0.79	10.6	17.7		1.520		2533.8	149.0
18	21.8	16.2	0.75	34.32	27.1	0.79	10.8	18.1		1.610		2683.9	149.1
19	23.3	16.6	0.71	34.96	27.6	0.79	11.0	18.4		1.750		2917.3	153.5
20	24.7	16.9	0.68	35.6	28.1	0.79	11.3	18.7		1.800		3000.6	150.0

Source: Field Survey, 2007

Note:
Max : Maximum
Dia. : Diameter
Avg. : Average
Ht : Height
H/D : Height/Diameter

Table 6: Benefit-cost analysis of *Sissoo* plantation for 10 and 20 years rotation

				Years																				
Area: 2 *Katha*				1	2	3	4	5		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Items	**Man days**	**Rate**	**Total**																					
Land preparation(manuring , plowing and weeding)	3	100	300	300																				
Pitting	5	100	500	500																				
Seedling cost (150)		**2.5**	**375**	**375**																				
Seedling transportation			400	400																				
Plantation	2	100	200	200																				
Weeding	2	100	200	200	200	200	200	200	200	200	200	200	200											
pruning								200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
fencing				5000																				
Opportunity cost (Cereal and cash crop)																								
Net income from Millet																								
Net income from Sugarcane				6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Net income from Vegetables																								
Disease/pest control				200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Final felling cost	25	100	2500											2500										5000
Total cost (year wise)				**13175**	**6400**	**6400**	**6400**	**6600**	**6600**	**6600**	**6600**	**6600**	**6400**	**8900**	**6400**	**6400**	**6400**	**6400**	**6400**	**6400**	**6400**	**6400**	**6400**	**11400**
Present value (PV) with 15% discount rate				**13175.0**	**5565.2**	**4839.3**	**4208.1**	**3773.6**	**3281.4**	**2853.4**	**2481.2**	**2157.6**	**1819.3**	**2199.9**	**1375.6**	**1196.2**	**1040.2**	**904.5**	**786.5**	**683.9**	**594.7**	**517.2**	**449.7**	**696.5**
Total PV (10 years)	**46353.9**																							
Total PV (20 years)	**54599.0**																							
Incomes																								
Income from intercropping																								
Vegetable																								
Sugarcane																								
Millet/Maize																								
Income from final felling														**307127**										**2950138.0**
Total benefits (year wise)																								
Total Present Value PV (10 years)	**75917.1**																							

Total Present Value PV (20 years)	**180254**																						
Net Present value (10years) (NPV) =	**29563.2**																						
Net Present value (20 years) (NPV) =	**125655.3**																						
B/C ratio (10 years)	**1.6**																						
B/C ratio (20 years)	**3.3**																						

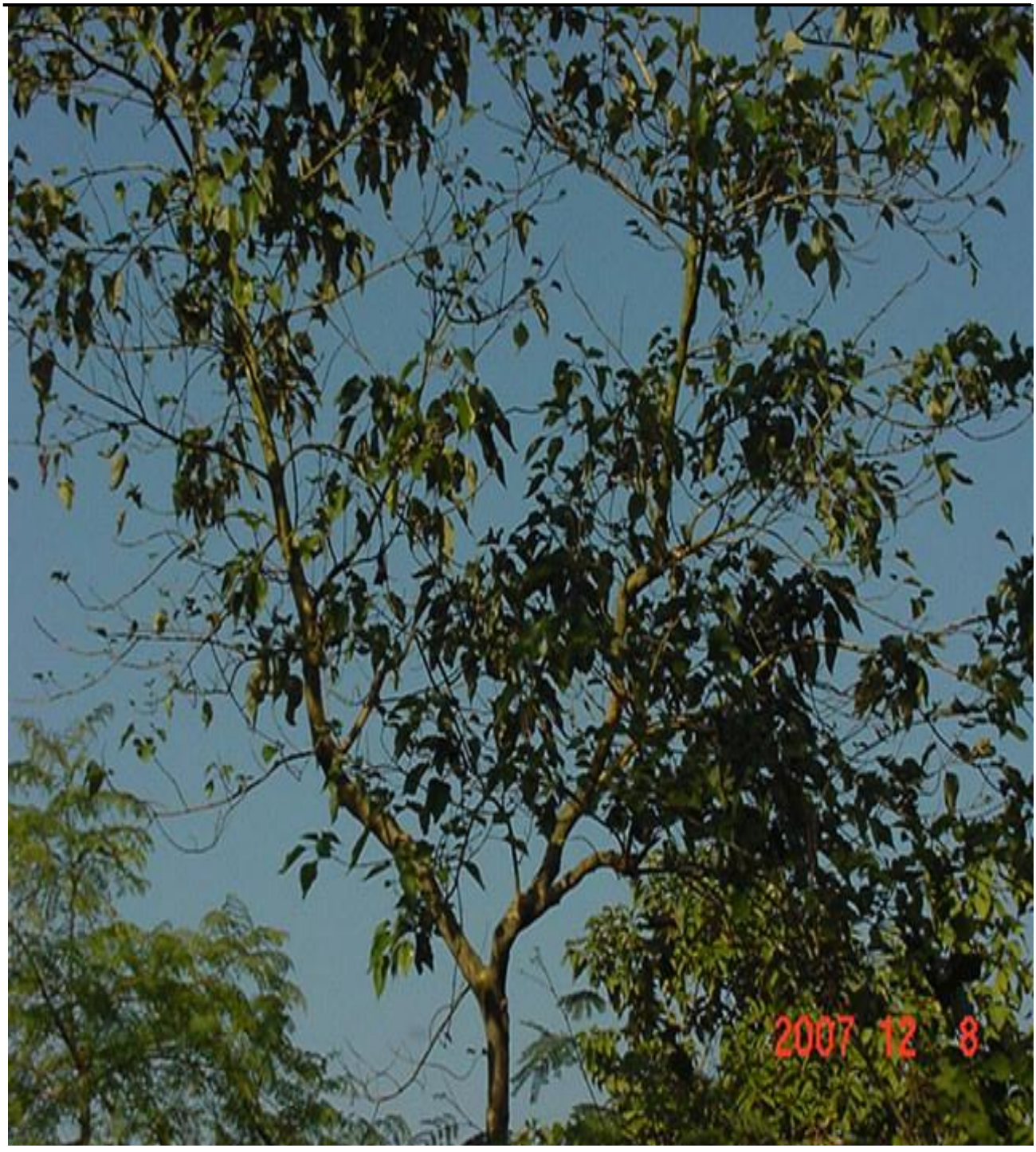
Source: Field Survey, 2007

D. Photo Plates

<table>
<tr><td colspan="3">  </td></tr>
<tr><td colspan="3">Sissoo Leaves</td><td colspan="2">Sissoo branch with pods</td></tr>
<tr><td>  </td><td colspan="2">  </td><td>  </td></tr>
<tr><td>Sissoo buds</td><td colspan="2">Sissoo bole</td><td>Sissoo pods</td></tr>
</table>

Eight year old *D.* s*issoo* plantati

GMELINA ARBOREA



White Teak
(Labiatae)
Khamari

A. Silviculture

1. Scientific classification

Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Lamiales
Family:	Verbenaceae
Genus:	*Gmelina*
Scientific Name:	*G. arborea* Roxb.
Local Name:	*Gambari, Khamari, Gamari, Gumhari*
English Name:	White Teak, Gmelina, Malay bush, beech wood, White beech

2. General introduction

Khamari is a deciduous tree with a clear bole. It coppices very well. It grows in semi-evergreen, sub-montane and mixed deciduous forests. *Gmelina arborea* is a fast growing tree that though grows on different localities and prefers moist fertile valleys with 750-4500 mm rainfall. The tree attains moderate to large height up to 40 m with girth of 1.2 to 4.5 m with a clear bole of 9-15 m. It has a smooth whitish grey (ashy) corky bark, warty with lenticular tubercles exfoliating in regular patches when old. It is commonly planted as garden and avenue tree and also in villages along agricultural land, on village community lands and on wastelands.

3. Silvicultural characteristics

It is tolerant of excessive drought but moderately frost hardy and has good capacity to recover in case of frost- injury. *Khamari* tree coppices very well with vigorous growth. Saplings and young plants need protection from deer and cattle. It is considered good for private forestry as it grows fast. *Gmelina* wood is relatively light with a density of 420 to 640 kg per m^3 and a calorific value of about 4800 kcal per kg. *G. arborea* begins to flower and set fruit at about 6 to 8 years. It is an especially promising fuel-wood species because it can be established easily, regenerates well from both sprouts and seeds and is fast growing. Although able to compete with weeds more successfully than many other species, it responds positively to weeding and also benefits from irrigation. Vigorous growth can be observed in sites under monsoonal climate with distinct dry period. When planting, holes should have sufficient depth. Plant should be free from competition at an early age until its crown has closed. G. *arborea* is a highly light-demanding species and regenerates naturally only in the open and on the edge of forests. It is an ideal choice for large-scale afforestation programs. It is sometimes planted as an avenue tree too. On good sites and with careful tending, young trees can attain a height of 5.5 meters in three years and diameter increment can be 2 cm/annum.

4. Geographic distribution

G. arborea is native to Nepal, India, Bangladesh, Sri Lanka, Myanmar, Japan, Thailand, southern China, Vietnam, Laos, Cambodia, and Sumatra in Indonesia. The species is widely introduced into many tropical countries, Brazil, Cote d'Ivoire, Ethiopia, Gambia, Ghana, Kenya, Malawi, Malaysia, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda and Zambia.

5. Morphology

Leaves

Leaves are petiolate. The petiole is 5-15 cm. long and puberulent to glabrous. The leaf blades are broadly ovate, 10-25 x 7.5-18 cm., cordate or truncate at base, long-acuminate at apex, entire at margin (but sometimes toothed or lobed on young plants), tomentose or at length glabrous above, densely and persistently tomentellous beneath with stellate hairs, and glanduliferous just above petiole. There are lateral nerves (5-10) per side of a leaf blade. Petioles are hairy.

Flowers

Flowers are many. They are short-stalked, nodding, 4 cm long, densely hairy, showy, yellow to reddish or brownish and 25-40 mm long. Calyx is bell-shaped, 5 mm long and 5-toothed. Corolla is bright orange-yellow or brownish-yellow with short narrow tube and 2-lipped. Stamens are 4 in 2 pairs inserted near base of tube. It contains pistil with elliptical 4-celled ovary having 1 ovule in each cell. Stigma is often slightly 2–4-forked (Figure 1).

Twigs

Twigs are stout and often slightly 4-angled.

Bark

Bark is light gray or gray-yellow, smooth, thin and somewhat corking, becoming brown and rough.

Seeds/Fruits

Drupes are ovoid - pyriform, 20-25 mm. long. They are orange-yellow when mature and aromatic. The endocarp is usually 2-celled and 2-seeded (or by abortion 1-seeded), or sometimes 3-celled and 3 seeded (Figure 1).

Figure 1: Flowering branch of *G. arborea* and its fruits

6. Phenology

Reproduction ecology

Seed years recorded from various locations show that the tree seeds well every year. There are 2 peak periods for floral bud burst, which may vary from year to year and with the local climatic conditions. The first flowers are borne 3-4 years after planting. In nature, self-pollination is discouraged by the floral morphology. However, in controlled self-pollination, flowers develop into fruits. Mature fruits are produced 1 week after flowering peak and fruiting may be spread over a 2-month period.

Blooming season

The panicles of yellow tubular flowers appear from February to March when the tree is leafless. Clusters of yellowish-brown flowers appear when the trees are generally leafless but some trees flower and fruit throughout the year.

Pollination ecology

Pollination is assisted by insects i.e. bees and birds i.e. passerine birds

Fruiting season

Fruiting starts from May onwards. The fruits ripen during the last few days of May to June. The fruits can be collected from the crown canopies or from the forest floor. Because fresh fruits are eagerly devoured by cattle, the seeds can also be collected from their excretion. However, collecting yellowing fruits from the trees is recommended.

Propagation ecology

The species can be propagated by seeds, cuttings, stumps and cleft grafting. For stump planting, seeds should be sown at the rate of 90 seeds per square meter. Seedlings are usually ready for stump preparation in 7–8 months and should have a root collar diameter of at least 2.5 cm. The stem and roots of seedlings should be pruned back to 5 cm and 20 cm respectively. Stump planting is not widely practiced due to high mortality.

Seed dispersal ecology

Dispersal is assisted by monkeys, bats and birds attracted by the smell of fruits. Monkeys ingest and excrete the seeds unaffected and contribute to dispersal.

Seed viability

Although seeds can be stored for one year with slight decrease in viability, it is advised to use the fresh seeds. If seeds can be stored at 4°C, it will remain viable for about three years. Based on experience, a 1000-seed weight is approximately 350 g and germination is 65%.

7. Habitat/ecology

Climate

Khamari grows up to 1,500 m altitude. But, it thrives well on sites with an elevation of up to 525 m (1,750 ft) above sea level. Annual rainfall is about 750-4,500 mm with a dry season up to 6 months. Mean annual temperature is 12-45 degree Celsius. It is not frost tolerant.

Soil

It can tolerate acidic, calcareous (soil containing sufficient calcium carbonate) and lateritic soil (any reddish soil developed from weathering composed mainly of oxides of iron, aluminum, titanium, and manganese). However, *Khamari* prefers moist, fertile sandy loam and well drained soils. It performs best on fresh, well-drained and fertile soils. It shows preference for fertile, deep, well drained and sandy loam soils in moist valleys.

8. Patterns of plantation

Pattern

Farmers prefer both the bund and stand plantation depending upon the availability of the land and labor. The bund plantation requires no land specially allocated as seedlings are planted along the bund of the cultivated field. The cost of establishment is lower in case of the bund as compared to the stand. Bund cultivation requires less effort in preparing field and hence requires minimum number of labors. One obvious benefit of the bund plantation to the plants is that they can use the manure and fertilizer applied in the field for the major crops. *Khamari* is one of the best timber species in the *Bhawar* region.

Spacing

It's a common practice that farmers prefer to have a one meter gap in case of bund plantation i.e. 101 seedlings in a 100 meter long bund while in case of stand, four different spacing systems are in practice i.e. 4*4 m^2, 3*2 m^2 , 2*2 m^2, 3*3 m^2. Spacing varies with objectives of the Plantation. When objective is to produce fuel-wood and poles, narrow spacing (2*2 m^2) is preferred to the wider one. For timber, obviously the preferred spacing would be the wider one (4*4 m^2 &3*3 m^2). 4.5*4.5 m^2 spacing is preferred for agroforestry.

9. Nursery techniques

Seed collection

One has to wait until the fruits become ripe with a green-yellow to orange color. Then they are collected from the floor. They can be collected when they are yellowish-green by shaking branches. *Khamari* should be collected twice a week because not all fruits are shed at the same time. Black fruits should not be collected. The *Khamari* fruits should be immediately soaked in running water during the night to loosen the pulp. During the day they are dried in the sun. This is repeated for 1 week. The fleshy cover is then rubbed of the stones by hand (Figure 2). To remove the remaining dry pulp from the stones they are rubbed with sand and water. In case of large scale collection, removal can also be done with sand in a cement mixer. The stones need further washing and then drying in the sun. Ripe brown fruits are collected from April to June from the ground, duly rejecting the green and black ones. Although seeds can be stored for one year with slight decrease in viability, it is advised to use the fresh seeds. Instead of soaking in the running water, fruits can be heaped under or buried in a pit for 4 to 5 days and then washed to remove pulp. After complete removal, seeds are dried in the sun.

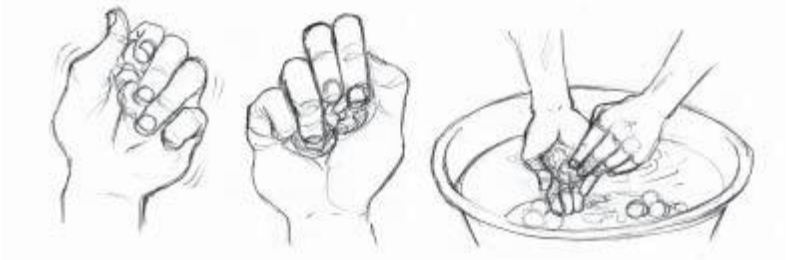


Figure 2: Extraction of stones by soaking the fruits in water and removal by rubbing.

Storage

When *Khamari* stones are dried in the sun for 2-3 days, they can be stored for 6 months up to several years in locally used airtight plastic containers of 5, 10 or 20 liter. Fresh seed can be stored at room temperature for about 6 months. Seed stored at 4°C will remain viable for about three years. They should be kept in a dry, cool and shaded room and protected against animals (Figure 3).

Figure 3: Keeping the *Khamari* stones in a cool and dry storage room, off the ground and ventilated.

Pre-treatment of seed

No pre-treatment is needed, but before sowing *Khamari* stones are soaked in water for 24-48 hours to speed up germination. Floating seeds should be discarded because they have been aborted, are nonviable, or both. Seeds are sowed in loosened soil and covered thinly (0.5 to 1.0 cm) with soil. Seeds can also be dibbled directly into prepared containers with appropriate media. Germination occurs 7 to 21 days after sowing.

Seed Biology

No. of depulped seeds per Kg.	***Germination percentage***	***Period of germination in days***
2500	13 to 90	15 to 21

Seed sowing in the poly pots

Seed is dibbled to a depth of 2 cm in the soil of poly bags in June to July. The growth of the taproot is slow. Polythene bags of 3/5 x 7 inches are suitable to raise *Khamari* seedlings. Soil mixture for the sowing bed and potting should contain one part sand and two parts topsoil from the forest. Up to 10 % rice husks can be used in the potting soil. 1 kg of fertilizer NPK 16-20-0 can be used in the potting mix, enough for 200 seedlings. Seedlings are ready for planting in the field when they reach a height of 30–45 cm, usually in 6 months.

Another method is transplanting seedlings from nursery bed to the poly-bags. In this method, stones should be sown in open sowing beds in September or October / March or April and covered lightly with straw. They need full sunlight for germination. When *Khamari* seedlings have the first pair of leaves after 30 days they are transplanted into containers (Figure 4). Seedlings grown in the nursery beds can be directly out-planted but the bare-root seedlings should have a minimum base diameter of 1 cm with a well balanced shoot-root ratio. Usually germination begins 7 days after sowing and may last for 20 days.

Figure 4: Transplanting of *Khamari* seedling into the polybags

Seed sowing in the nursery beds

The following are the steps in raising seedlings in the nursery beds:

1. Prepare raised germination beds about 1 m wide of desired length. Remove stones and under composed organic matter. Pulverize and level the clods.
2. Sow seeds 6 cm – 8 cm along rows and 8 cm – 10 cm between rows to attain production of seedlings with large stems and more fibrous roots. Cover lightly with soil, preferably compost litter. Seeds are sown in March-April.
3. After sowing, water the beds using sprinkler. Do this twice a day to make sure that seeds and soil are sufficiently wet. Shading is not necessary except for newly planted seeds.
4. Regulate the time of sowing in order to produce stumps not larger than 5.08 cm or 2 inch in diameter at the time of planting. Germination usually takes place two to four weeks.

Fertilizer application

Improper fertilizer use cases a high mortality rate in connection with fungi attack. *Khamari* seedlings respond very well to fertilizer NPK 16-20-0 application with a fast growth of its shoot. One application of 5 gram per seedling in March-April is recommended.

Weeding

Weed control is not necessary since after transplantation the seedlings develop very fast and shade out weeds. But in case of seedlings raised in the nursery beds, regular weeding is necessary to avoid competition. Watering is most after each weeding.

Watering

Regular watering is required to keep the nursery and poly bags moist. Care should be taken that watering should not create water logging condition in the nursery bed because water logging may cause damping off.

Root pruning

The development of the *Khamari* seedlings is fast and they are planted after 7-8 months, so root pruning is not necessary.

Hardening off

Hardening off can be done by removing the shade net in the beginning of May, 1 month before planting the seedlings out.

Shade and shelter

Khamari seedlings are raised in 75-100 % sun-light. Since they are planted out at the beginning of the first rainy season protection against heavy rain is not necessary.

Insects and fungi

Damping-off fungi and some insects may cause damage. Water management and planting density should be adjusted to avoid damping-off. Also the seed can be treated by drenching it with *thiram* fungicide (at 0.1 - 3 % wt of seeds) or with Delsene MX (2.5 grams per kg of seeds). Insects or plants can be removed by hand and should be burned.

Nursery pathogens include *Pythium splendens*, which causes wilting in 1-2 month old seedlings; and *Rhizoctonia solani*, a root-collar disease on 4-month-old seedlings. Anthracnose disease caused by *Colletotrichum sp.* is also reported.

10. Establishment of plantation

G. arborea can be planted in the field after reaching height of 23 – 30 cm which is achieved after 3 – 4 months old. Sometimes stump are used for artificial regeneration. However, due to high mortality during stump application, the technique is rarely used anymore. Sometimes, direct seeding in the field is also conducted. Young seedlings grow quickly and reach appropriate size for out-planting in 2 to 3 months.

Site preparation

Deep and fertile soils should be selected for planting sites. *Gmelina* does not do well when established on ridges and steep slopes where soils are shallow, dry, and poor in nutrients. Soil

preparation can be done by digging planting holes in June just before planting. In areas with heavy growth of weeds intensive manual weeding before planting is needed which can be placed as mulch around the seedlings. Some of the objectives of site preparation are the reduction of competition, improvement of adverse soil conditions, reduction of future fire hazard and increasing the availability of resources by improving the quality and/or quantity of soil volume exploited by tree roots. *Khamari* when damaged by fire is able to re-sprout. However, a firebreak is necessary to make when much and tall weeds attract bush fires. A firebreak around the planting site can be made by plowing, digging or controlled burning.

Planting season

Planting can be done in June and July. When seedlings reach height of 30 cm, they are ready for out-planting in the field. Generally *Khamari* seedlings attain this height in 7 to 8 months.

Fertilizer application

In poor sites, survival of out-planted seedlings and growth is improved by application of complete fertilizer. About 30 days after out-planting, apply the fertilizer in the soil at the rate of 50 gm/seedlings (NPK-16-20-0) to improve diameter, height growth and survival. Fertilizer is placed in trench about 5 cm deep and 5 cm away from the base of the seedlings and covered with soil. The second application can be done about 90 days after out-planting time.

Replacement planting

Replacement planting can be done a year later in June and July.

Weeding

Because *G. arborea* is shade-intolerant and sensitive to competition, 3–4 weedings are required during the first two years of growth.

Pruning

Lower branches are required to be pruned at an early stage to avoid development of large knots in the harvested timber.

Protection against fire and cattle

Khamari seedlings need fence protection against cattle and buffaloes which eat the leaves. To avoid fire, fire lines of 5 m width need to be constructed in which grasses are completely scraped off and extending around the plantation. For firebreaks, fire-resistant shrubs or trees in a belt fashion can be planted. Species used for this purpose includes wild banana, guava and ipil-ipil.

Thinning

The use of thinning depends on the purpose for raising *Gmelina*. Rotations for pulpwood and sawn wood and fuel-wood are usually 6, 10 and 5–10 years respectively.

Stands on 10-year rotations for fuel-wood production are thinned to 50% at five years and another 50% at seven years. The second rotation is usually produced by coppicing. Seedlings and stumps are planted for a third rotation. For fuel wood, spacing at 2 x 2 m is recommended, wider spacing for timber plantations. For the first year or so, weeding is necessary, but the canopy is soon dense, like the litter layer, quickly arresting the weed growth.

Gmelina plantations raised for timber can be thinned twice in a rotation period of 15-20 years. The first thinning is done at the age of 3 years and the second thinning is at the age of six. Thinning intensity is 15-20% of the total stand in the first thinning and 35-40% in the second.

11. Diseases and pests

Where it is introduced, it has few disease problems although some sporadic cases have been reported. Plantation diseases observed include the followings.

Disease	**Causal Pathogen**
Leaf spot	*Colletotrichum gloeosporioides*
Vascular necrosis & chlorosis	*Pestalosphaeria elacidis & Khuskia oryzae*
Heart rot and root rot	*Ganoderma spp*
Stem and branch canker	*Ceratocystis fimbriata*

One of the insects consistently associated with the species is a carpenter worm *Prionoxystus sp*. which bores into stems of saplings feeds from within and weakens them. Serious plantation pests are the larvae of *Dihammus cervinus*, which bores longitudinal galleries on the cambial layer of the saplings and the larvae of *Calopepla leayana* and *Glenea indiana*.

The most destructive insect of *Gmelina* is the Ozola minor (Lepidoptera: Geometridae), a small moth whose larvae feeds on the leaf. When infestation is very light, the larvae can be handpicked and killed. . In heavy infestation, especially in young plantations, the leaves are spayed with the recommended commercial dose of either Malathion 50 RC, Gusathion,Parapest, or Ferminthrin every 2 weeks, if necessary.

Some economically important pests and pathogens and their control measures

A. Diseases

1. Sooty mold

Symptom

Leaves, petioles, twigs, and branches are partially or completely covered with black mycelial colonies of fungus. The leaves become grayish black and later turn to dirty brown and defoliate.

Causal pathogen

Meiola clerodendricola

Control measure

If damage is serious, control first the insect using organic phosphorus chemicals. Improvement of environmental conditions through thinning or pruning is also effective measures in suppressing sooty mold disease

2. Brown leaf spot

Symptom

Production of water-soaked and necrotic lesions at the base of the stem of infected seedlings causing wilting and toppling of seedlings over the seedbeds

Causal pathogen

Rhizoctonia solani Kuhn, Sclerotium spp., Fusarium spp., Pythium spp., and Pythopthora spp

Control measures

1. Sterilize soil for 7 – 8 hrs at 180oC with intermittent spraying of water before putting in seed boxes
2. Disinfect soil before seeding. Drench soil with diluted emulsion of Thiram or Captan (3 – 6 li/sq m of soil). Soil burning is also recommended.
3. Seed treatment. Dress the seeds with thiram fungicide (0.13% wt of seeds) or with Delsene MX (2.5 liter/kg of seeds).
4. Seedlings should be kept in well-drained soil.
5. Soak seedlings in fungicide solution for 5 hrs (Benlate at 2.5 g/lit of water) before transplanting to plastic pots

B. Pests

***1. Lepidopterous defoliators (Chrysodeixis chalcites, Archerontia lachesis* and *Attachus* spp)**

These have been observed seriously infesting seedlings in nurseries and plantations in Nueva Ecija. Their larvae feed occasionally on leaves, leaving only the midribs. Infestation occurs every year. While some plants succumb completely to the attack, some recover to produce new shoots.

Control Measures

Spray any of the Carbaryl insecticides such as Sevin 85S, Vetox 85 WP or Carbin 85 S at the rate of 15 – 25 tablespoons per 100 lit of water at a five-day interval. Spray the leaves when egg masses and larvae are noticed.

2. Ozala minor

A monophagous species which occurs in the early part of May and in the middle part of July recurs in the latter part of November and ends in the latter part of January. It actively feeds at early in the morning and late in the afternoon. Newly hatched larvae feed on any part of the leaves which later become perforated. Leaf margins are sometimes eaten. Young larvae prefer newly opened leaves although mature larvae also feed on older leaves. When infestation is extremely heavy, the entire leaf may be consumed except the midribs and large margins. Pest is likely to be serious in seedlings and young stands where more growing shoots occur.

3. Leaf cutter ants

These can be controlled by insecticides or poisonous gases provided the expenditure or cost is justified and application is done with proper caution. It can also be controlled by the use of small explosives

12. Intercropping

Planting G. *arborea* with crops like maize has been found beneficial in increasing the simultaneous production of wood and food. Some limitations are that it casts heavy shade, and nothing will grow under a dense 2 x 2 m stand; it forms a leaf carpet beneath trees, creating a mild fire hazard in times of prolonged drought; and the palatability of the foliage is a drawback to establishing woodlots near villages.

13. Uses

Khamari is valuable for its light construction wood, furniture, fuel wood, charcoal and pulp. Bark is used for tannin and dye, roots and flowers are used in local medicine. Leaves can be used as fodder for cattle and is recommended for silkworm culture. Its fruits are edible.

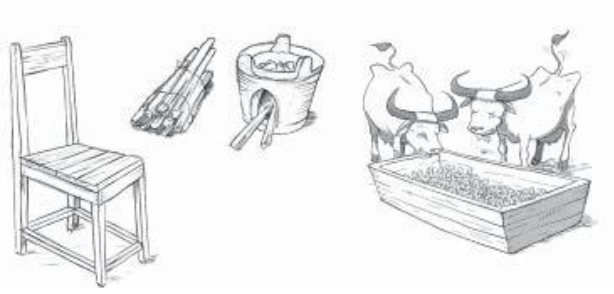


Figure 5: Various use of *Khamari* tree

G. arborea timber is reasonably strong for its weight. It is used in constructions, furniture, carriages, sports, musical instruments and artificial limbs. Once seasoned, it is a very steady timber and moderately resistant to decay and ranges from very resistant to moderately resistant to termites. In instrument industry *Khamari* timber is widely employed for the manufacture of drawing boards, plane tables, instrument boxes, thermometer scales and cheaper grade metric scales. It is also used in artificial limbs, carriages and bobbins (Figure 5). It is an approved timber for handles of tennis rackets, frames and reinforcements of carom boards and packing cases and crates. *Khamari* is used in papermaking and matchwood industry too. Its timber is highly esteemed for door and window panels, joinery and furniture especially for drawers, wardrobes, cupboards, kitchen and camp furniture, and musical instruments because of its lightweight, stability and durability.

The root and bark of *G. arborea* are stomachic, galactagogue laxative and anthelmintic; improve appetite, useful in hallucination, piles, abdominal pains, burning sensations, fevers, 'tridosha' and urinary discharge. Leaf paste is applied to relieve headache and juice is used as wash for ulcers. Flowers are sweet, cooling, bitter, acrid and astringent. They are useful in leprosy and blood diseases.

In *Ayurveda* it has been observed that *Khamari* fruit is acrid, sour, bitter, sweet, cooling, diuretic tonic, aphrodisiac, alternative astringent to the bowels, promote growth of hairs, useful in 'vata', thirst, anemia, leprosy, ulcers and vaginal discharge. The plant is recommended in combination with other drugs for the treatment of snake – bite and scorpion- sting. In snake bite a decoction of the root and bark is given internally.

B. Growth performance

1. Study design and methods

1.1 Study area description

Data presented in the book were collected from the central development region of Nepal, *Dhanusha* district, the project area of Nepal Agroforestry Foundation (NAF), where NAF has been working for 15 years for promoting private forestry in the district. The study covered nine VDCs of the district, where farmers have established stands of *Khamari* of different age ranging from year 3 to 15 years old. The geography of the area is very fragile and soil is sandy and hence the water holding capacity of the area is very low.

1.2 Sample size and sampling intensity

Stands with at least 5 *Kathas* (30 *Kathas* = 1 hectare) of coverage were taken into consideration for the study. Two major variables were measured: Diameter at Breast Height (DBH) and Height. Data were collected from the stands aged 3, 7, 11 and 15. There were altogether 12 stands measured (3 replications). Site quality has been assumed to be the same in each stand. Since the stands are from the same source i.e. NAF's nursery, author assumes that the stand performs the similar growth pattern. The sampling size (unit) was 5*5 m^2 with 2 % sampling intensity. The sampling units were randomly selected. Based on the data from the sample plots, Current Annual Increment (CAI) was

calculated and a table was developed which gives the possible DBH and height for each age from 3 to 15.

In case of bund plantation, individual tree was considered as sampling unit and the first one was selected randomly and rest was selected systematically i.e. every third tree. Therefore, the method selected for the bund was systematic sampling with random start.

2. Findings

2.1 Growth performance in the bund and the Stand (Based on average diameter)

The average diameter of the 15 years old plantation is 25.8 cm and 28.5 cm in stand and bund respectively. Even though the average growth of the two plantation patterns does not vary, the initial growth being higher in case of the bund plantation, the bund crop reaches the size 25.8 cm in 13 years, assuming the constant rate of growth over time within a class interval (Table 1).

The growth rate varies with the plantation pattern. The growth is decreasing more rapidly until 11 in the stand than in the bund but after 11, the rate of growth decreases sharply in the bund. The MAI is slightly higher in the bund than in the stand (Table1). The variation in growth in early age is higher and it decreases at the crop reaches to its maturity and the Stand to bund growth ratio (S/B ratio) tends to be almost 1 in the later age (Table 1). Conclusion can be drawn that the trees having rapid growth in its early age tends to decrease with age and similarly the trees having comparatively slow growth at early age tends to increase its growth with age to some limit.

Table 1: Growth pattern over time in DBH (cm)

Pattern	Age (Years)													MAI (cm)
	3	4	5	6	7	8	9	10	11	12	13	14	15	
Stand	3.9	6.0	8.1	10.2	12.3	14.3	16.3	18.3	20.3	21.7	23.1	24.4	25.8	1.72
Bund	5.7	7.6	9.5	11.4	13.3	15.7	18.1	20.5	23.0	24.3	25.7	27.1	28.5	1.90
Ratio	0.68	0.79	0.85	0.89	0.92	0.91	0.90	0.89	0.88	0.89	0.90	0.90	0.91	0.90

Source: Fiend Survey, 2007

2.2 Growth performance in the bund and the stand (Based on maximum diameter)

In the initial age until 4, the growth pattern differs slightly in these two modes of plantation. After six until 4**,** the growth pattern is almost similar in this plantation. Highest difference is seen at the age of 4 (Table 4). Assuming the constant increase in growth within each age class, the following growth has been projected for every age within each class. The 37.8 cm size is achieved in 14 years i.e. one year prior to the stand crops. The MAI is slightly higher in the bund than in the stand. The Stand to bund growth ratio (S/B ratio) after 6 years tends to be almost 1, indicating that there is not much difference in growth between the two modes of plantation (Table 2).

Table 2: Growth pattern over time in DBH (cm)

Pattern	Age (Years)													
	3	4	5	6	7	8	9	10	11	12	13	14	15	MAI
Stand	4.7	8.4	12.1	15.8	19.5	23.3	27.0	30.8	34.5	35.3	36.2	37.0	37.8	2.52
Bund	9.2	12.2	15.3	18.3	21.4	24.7	28.0	31.2	34.5	35.5	36.5	37.5	38.5	2.60
Ratio	0.51	0.69	0.79	0.86	0.91	0.94	0.96	0.99	1.00	1.00	0.99	0.99	0.98	0.97

Source: Fiend Survey, 2007

2.3 Productivity of the stand and bund (Based on the average diameter)

As the tree reaches its maturity, the B/S ratio tends to be 1 indicating that the trees having initial fast growth will exhibit comparatively slower growth rate at later age. Until 5, bund tree performs better than the stand tree does. When a tree reaches 15, the average BA is almost same. To achieve 87.1 m^2 BA in 15 years, about (87.1/6.4) i.e. 14 bunds of 100 meter long is required. Hence, a 1400 meter long bund produces the Basal Area (BA) equal to the one hectare stand of 15 years (Table 3).

Table 3: Productivity of a stand and a bund in terms of basal area (m^2)

Pattern		**Age (years)**												
	Parameters	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	12	13	14	15
Bund (B)	BA/tree	0.003	0.005	0.007	0.01	0.013	0.02	0.023	0.03	0.04	0.04	0.05	0.05	0.06
	BA/100m	0.3	0.5	0.7	1.0	1.4	2.0	2.6	3.4	4.2	4.7	5.3	5.8	6.4
Stand (S)	BA/tree	0.001	0.003	0.005	0.008	0.012	0.016	0.021	0.026	0.032	0.037	0.042	0.047	0.052
	BA/Ha	2.0	4.7	8.6	13.6	19.8	26.7	34.7	43.8	53.9	61.5	69.5	78.1	87.1
	B/S Ratio	0.3	0.6	0.7	0.8	0.9	0.8	0.9	0.9	0.8	0.9	0.8	0.9	0.9

Source: Field Survey, 2007

2.4 Productivity of the stand and bund (Based on the maximum diameter)

The individual tree BA of the bund is three times more than the stand BA until 3 and this continues to decrease with maturity. After 9, the B/S ratio tends to be 1, which indicates the BA in both cases is same at later age (Table 4).

Table 4: Productivity of a stand and a bund in terms of basal area

		Age (years)												
Patterns	**Parameters**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	12	13	14	15
Bund (B)	BA/tree	0.007	0.012	0.018	0.026	0.036	0.048	0.061	0.077	0.093	0.099	0.105	0.110	0.116
	BA/100m	0.7	1.2	1.9	2.7	3.6	4.8	6.2	7.7	9.4	10.0	10.6	11.1	11.8
Stand (S)	BA/tree	0.002	0.006	0.011	0.020	0.030	0.042	0.057	0.074	0.093	0.098	0.103	0.107	0.112
	BA/Ha	2.9	9.2	19.2	32.7	49.8	70.7	95.4	123.7	155.8	163.3	171.0	178.9	187.0
	B/S Ratio	0.3	0.5	0.6	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0

Source: Field Survey, 2007

C. Economics and trade

1. Introduction

The general mode of trade for timber, poles and fuel-wood is basically contractor-based. The local contractors collect wood (timber and poles especially) from the private tree growers and sells them either in the local market i.e. saw mill owners or directly transport to the big city centers like *Kathmandu*, *Pokhara* and *Narayanghat* and *Janakpurdham*. Besides, some farmer-led organization has also taken initiatives for marketing and trade of their forest products. For example, the Terai Private Forest Development Association (TPFDA) in *Dhanusha* district, which is supported by Nepal Agroforestry Foundation (NAF), is engaged in timber and pole marketing to avoid the contractor-based marketing channel for the benefits of private tree growers.

2. Methods of market study

This study only covered the local level market scenario of the timber. For this, author had selected only five saw mills out of 20 currently running within the project area. The purpose of saw mill survey was to find out the size of timber in demand in local market and trend of price of timber over time according to its size. The price of the species for each size from 2002 to 2007 has been collected and presented in the table 5.

3. Market value

In terms of monetary value, this species falls on the top. Logs with sizes 2ft, 3ft and 4 ft can be sold in higher price than s*issoo* logs of the same sizes. Its market price is exactly similar to the teak. The local level contractors buy the *Khamari* logs from farmers and sell them either in the local sawmills or in *Kathmandu* or *Janakpur*.

4. Marketable size

The preferred size by the local saw mills runners varies from 2 ft to 5 ft in girth and the price is fixed accordingly. The minimum length fixed for a log is 6ft (Table 5). If any log smaller than 6 ft, that is not considered suitable for producing the desired size for furniture. Therefore the rate for such timber will be fixed randomly by the sawmill owners. The biggest size is 8 ft, which is rarely produced and sold.

5. Market price scenario over time

In the last six years, there has been definitely a change in market price of *Khamari* wood in every size excluding the size 4 ft. The rate of growth in price is higher in smaller size timber than in the bigger ones (Table 5). Therefore, in long run, producing small size timber is far better from financial point of view.

Table 5: Market price of the *Khamari* wood in local sawmills

Dimension						Volume	Rate/Cft	Year-wise price/c ft						
Girth (ft)	**DBH (ft)**	**DBH in inch**	**DBH in Cm**	**<, >**	**L(ft)**			2002	2003	2004	2005	2006	2007	**Increase in price (%)**
2 (I)	0.6	7.6	19.4		**6**	1.91	**200**	**125**	**125**	**125**	**125**	**150**	**200**	10.%
3 (II)	1.0	11.5	29.1		6	4.30	300	250	250	250	300	300	300	3.9%
4 (III)	1.3	15.3	38.8		6	7.64	400	400	400	400	400	400	400	
5 (IV)	1.6	19.1	48.5		6	11.94	500	450	450	450	450	450	500	2.2%

Source: Field Survey, 2007

6. B/C ratio and rotation period

There are three sizes (I, II and III) basically in demand in the local market (Tables 5) The first three sizes are attained at the age of 7, 9 and 15 years respectively based on the highest diameter and highest height in the stand. Therefore three rotation periods have been recommended according to the market demand. If we harvest the crop at 7, we will have two rotations in 15 years period (Tables 5, 6, 7, &8,). Which one is the best rotation can be assessed only if we have data on which size class is most preferred among the two size classes by the saw-mill owners.

Table 6: Productivity of a teak stand based on maximum/Average Diameter and height

Age	Avg. Diameter (cm)	Avg. Height (m)	H/D	Max. Dia (cm)	Max. Height (m)	H/D	Marketable length(m)		Density/ha	Avg. log volume		Total volume/ha (m^3)	
							Average	Maximum	$(3*2)m^2$	Average	Maximum	Average	Maximum
4	6	7.2	1.2	8.4	8.4	1.0	4.8	5.6	1667				
5	8.1	9.7		12.1	10.3		6.5	6.9					
6	10.2	10.7		15.8	13.4		7.2	9.0					
7	12.3	11.1	0.9	19.5	13	0.7	7.4	8.6		0.08	0.12	140.0	200.0
8	14.3	12.6		23.3	16.3		8.4	10.9		0.13	0.15	215.0	247.3
9	16.3	14.4		27.0	19		9.6	12.6		0.19	0.22	321.7	370.0
10	18.3	15.7	0.9	30.8	21.0	0.7	10.5	14.0		0.24	0.28	405.4	466.2
11	20.3	16.2		34.5	22.4		10.8	15.0		0.31	0.35	510.8	587.4
12	21.7	17.4		35.3	23.0		11.6	15.3		0.39	0.44	643.6	740.1
13	23.1	17.2	0.8	36.2	25	0.7	11.5	16.3		0.49	0.56	810.9	932.6
14	24.4	19.5		37.0	27.0		13	18.0		0.61	0.70	1021.8	1175.0
15	25.8	20.6		37.8	27.6		13.8	18.4		0.77	0.72	1287.4	1200.2

Source: Field Survey, 2007

Table 7: Income from different size class wood of *Khamari*

	Market prices for different dimensions										
	Dimension (in feet)										
Size Class	**Girth(ft)**	**DBH**	**DBH in inch**	**DBH in Cm**	**<, >**	**L(ft)**	**Vol. in cuft**	**Vol. in m3**	**Rate/Cft**	**rate/m3**	Total price (NRs.)
Size I	2	0.6	7.6	19.4		**6**	1.91	0.05	200	7057.5	382.2
Size II	3	1.0	11.5	29.1		6	4.30	0.12	300	10586.3	1289.8
Size III	4	1.3	15.3	38.8		6	7.64	0.22	400	14115.0	3057.3
Size IV	5	1.6	19.1	48.5		6	11.94	0.34	500	17643.8	5971.3
Size IV	8	2.5	30.6	77.7	(Biggest Size)						
Possible income from the sale of the timber at the age 7, 9 and 15											

	Age	DBH	Vol/tree	Vol/2katha	vol. Size I	Vol. Size II	Vol. Size III	Nos. of logs	density/2katha	rate/log	Total price (NRs.)
	7	19.5	0.1		0.05			2.4	111	382.2	**101818.08**
	9	27.0	0.2			0.12		1.8	111	1289.8	**262474.3**
	15	37.8	0.7				0.25	2.9	111	3057	**977261.76**

Source: Field Survey, 2007

Table 8: Benefit- cost analysis of the *Khamari* stand at the age 7, 9 and 15

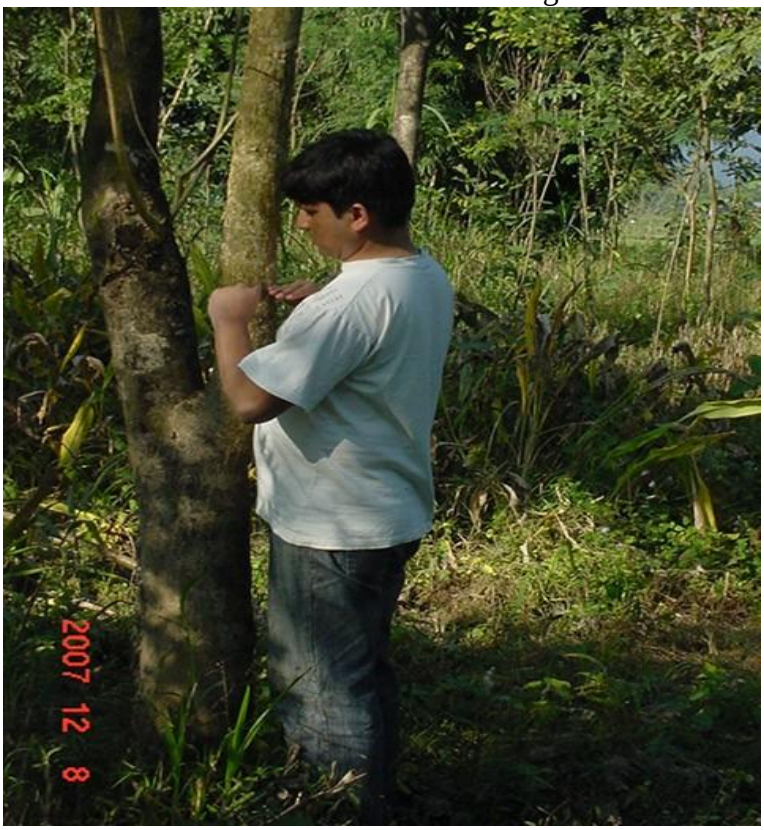
				Years														
Area: 2 *Katha*				**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
A. Costs																		
Items	**Man days**	**Rate**	**Total**															
Land preparation	2	100	200	200														
Pitting	4	100	400	400														
Seedling cost	150	5	750	750														
Seedling transportation			350	350														
Weeding	2	100	200	200	200	200	200	200										
Pruning									100	100	100	200	200	200	200	200	200	200
Fencing				5000														
Opportunity cost (Cereal and cash crop)																		
Net income from Millet				2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Net income from sugarcane																		
Net income from vegetables																		
Disease/pest control					200	200	200	200	200	200								
Final felling cost	25	100	2500							2500		2500						3500
Total cost				8900	2400	2400	2400	2400	2300	4800	2100	4500	2200	2200	2200	2200	2200	5700
Present value (PV) with 15% discount rate				8900	2087	1815	1578	1372	1144	2075.17	789	1471.058	625	543.8	472.9	411	357.6	805.57
Total PV (7 years)	**18970..00**																	
Total PV (9 years)	**21231.15.00**																	
Total PV (15 years)	**24447.54.00**																	
B. Benefits																		
Income from intercropping																		
Vegetable																		
Sugarcane																		
Millet/Maize																		
Income from final felling										**101818**		**262474**						**977262.0**

Total benefits (Year wise)										**101818**		**262474**						**977262.0**
Total PV (7 years)	**44018.73**																	
Total PV (9 years)	**85803.31**																	
Total PV (15 years)	**138115.1**																	
NPV (7 years)	**25048.1**																	
NPV (9 years)	**64572.2**																	
NPV (15 years)	**113667.6**																	
B/C (7years)	**2.3**																	
B/C (9 years)	**3.0**																	
B/C (15 years)	**4.6**																	

Source: Field Survey, 2007

D. Photo plates

3 month old seedlings



Researcher locating the breast height for diameter measurement

Four years old *Khamari* Plantation

Khamari fruits

Khamari Flowers

Khamari seeds

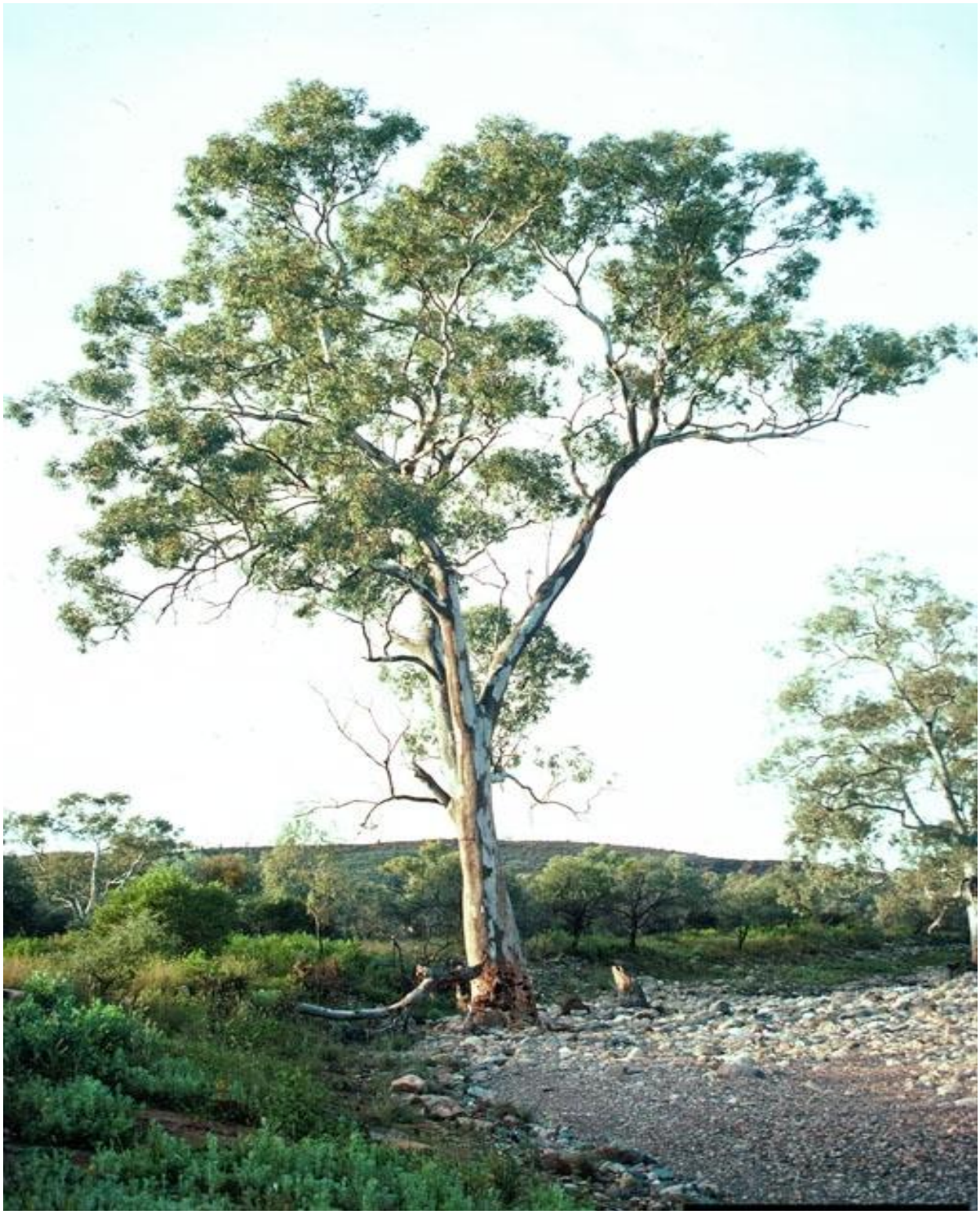
Inflorescence

Khamari Bole/bark

Khamari Tree

Inflorescence

EUCALYPTUS CAMALDULENSIS



River Red Gum
(Myrtaceae)
Masala/Vicks

A. Silviculture

1. Scientific classification

Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Myrtales
Family:	Myrtaceae
Genus:	Eucalyptus
Scientific Name:	*E. camaldulensis* Dehnh.
Local name:	*Masala, Vicks*
English Name:	River Red Gum

2. General introduction

The River Red Gum (*Eucalyptus camaldulensis*) is a tree of the genus *Eucalyptus*. It is a plantation species in many parts of the world but is native to Australia where it is widespread especially beside inland water courses. Oddly, it is named for the Camaldoli monastery near Naples, from where the first specimen came to be described. It is a familiar and iconic tree seen along many watercourses right across inland Australia. The tree produces welcome shade in the extreme temperatures of central Australia and plays an important role in stabilizing river banks, holding the soil and reducing flooding.

3. Silvicultural characteristics

Eucalyptus camaldulensis is very fire sensitive and even low intensity fires may cause cambial injury. Fire kills regeneration and even mature trees are susceptible if the fire is intense enough since *E. camaldulensis* lacks a lignotuber. Fire will cause damage to the butt, lowering the value of the timber and predisposing tree to fungal and insect attack. It is a semi-deciduous medium size tree up to 40m tall and up to 0.8 m in diameter. It is a fast growing species. It is one of the most preferred species for agroforestry in central *terai* of Nepal. It is good for fuel-wood and pole production.

4. Geographic distribution

Masala is an exotic species for Nepal, which is introduced from Australia where it grows in semi-arid lowland areas. It is one of the most widely planted eucalypts in the world. Plantations occur in Argentina, Arizona, Brazil, California, Egypt, Kenya, Morocco, Nigeria, Pakistan, Senegal, Sierra Leone, Spain, Sri Lanka, Sudan, Tanzania, Upper Volta, Uruguay, and Zimbabwe.

5. Historical background of *Eucalyptus* plantation

Eucalypt was introduced in Nepal some 50 to 60 years ago and planted as avenue trees along road sides in the *Kathmandu* valley at the altitude of 1,350 meter. Elsewhere, a few small stands of eucalypts can be seen in the hills that have mainly been established for trial and demonstration

purposes. Although growth has been reasonable, *Eucalyptus* species do not seem well suited to the elevation and climate conditions of the hills of Nepal.

Although the growth the *Eucalyptus* in hills has been disappointing, the situation is very different in the Terai where elevations are generally below 300 m. At *Sagarnath* (150 m.) in eastern Nepal on the Terai, there are some quite promising eucalypt plantations. During 1981-85, Mr. K.J. White established several *Eucalyptus* species trials as well as plantations at *Sagarnath* for the primary purpose of fuel wood production. Experience indicates that *E. camaldulensis* is suited for this area for its general adaptability to sites and conditions found in the *terai* as well as its high yield and utility for a variety of products currently in demand in the area.

6. Morphology

Eucalyptus camaldulensis is a perennial, single-stemmed, large-boled, and medium-sized to tall tree. According to Jacobs (1955) river red gum could reach ages of 500 to 1000 years.

Leaves

Leaves are alternate (may be opposite on young branches), simple, evergreen, leathery, ovate to narrowly lanceolate, 4 to 8 inches long, often curved and drooping, and long pointed. They are aromatic. They are dull green above, bluish bloom beneath. Young foliage is more blue.

Flowers

Flowers are round with very long creamy white stamens, no petals and hence making it look like a round bottle brush. They appear singly in leaf axils in winter and early spring. Fruits are dry, heavy capsules, 1/2 inch wide, looks like a wooden top.

Twigs

They are slender, yellow-green to reddish and smooth.

Barks

Barks are attractive and peel in long loose strips, often piling up at base. The outer bark is rough reddish brown and the inner bark is smooth creamy white to yellow-green.

Form

E. camaldulensis is a large tree with a straight trunk that can reach 200 feet tall and several feet in diameter. The tree trunk is more or less cylindrical.

7. Phenology

Reproduction ecology

The eucalypt breeding system is one of mixed mating with preferential out-crossing. Although eucalypts are commonly self-compatible, self-pollination generally results in a reduction in capsule

production, seed yield and seedling vigor. Analyses of the breeding system of *E. camaldulensis* indicate a predominantly out-crossing mating system.

Blooming season

Eucalyptus flowers in most years from June to July.

Pollination Ecology

Pollination is mainly by insects but also by birds and small mammals

Fruiting Season

Fruit development and maturation time can be as short as four months. Number of viable seeds per unit weight of a seed lot is 698,000/kg in an average. The fruiting season is December to January.

Seed viability

It reproduces good crops of seeds every year or two. Seeds are long lived when stored in sealed container in dry cold storage.

8. Habitat/ecology

E. camaldulensis commonly grows on riverine sites, whether of permanent or seasonal water. It is most extensive on grey heavy clay soils along river banks and on floodplains subject to frequent or periodic flooding, preferring deep moist sub-soils with clay content. It can adapt to a variety of soils. It tolerates periodic water logging. With its heavy and wide spreading crown, it is a good shade tree and planted along the roadside.

Climate

Masala is often planted on altitudes up to 1,800 m. Mean annual rainfall ranges from 500-5,000 mm. It tolerates a dry season of 4-6 months. Mean annual temperature is13-33 degree Celsius.

Soil

Masala tolerates infertile acid sandy or rocky soils, or water-logging. *E. camaldulensis* demonstrates moderate salt tolerance. Increasing salinity is associated with reduced tree growth. Growth is better for *E. camaldulensis* trees planted on non-saline soil than on moderately saline soil. An increase in soil salinity was associated with a decrease in the average leaf area per tree.

9. Patterns of plantation

Pattern

Farmers prefer both the bund and stand plantation depending upon the availability of the land and labor. The bund plantation requires no land specially allocated as seedlings are planted along the bund of the cultivated field. The cost of establishment is lower in case of the bund as compared to the stand. Bund cultivation requires less effort in preparing field and hence requires minimum number of labors. One obvious benefit of the bund plantation to the plants is that they can use the manure and fertilizer applied in the field for the major crops.

Spacing

It's a common practice that farmers prefer to have a one meter gap in case of bund plantation i.e. 101 seedlings in a 100 meter long bund while in case of stand, three different spacing systems are in practice i.e. 3*2 m^2 , 2*2 m^2, 3*3 m^2. Spacing varies with objectives of the Plantation. When objective is to produce fuel-wood and poles, narrow spacing is preferred to the wider one. For timber, obviously the preferred spacing would be the wider one.

10. Nursery techniques

Figure 1: *Masala* Seeds

Seed collection

Ripen seed (Figure 1) is collected only from seed trees which are older than 8 years and after the second or third time of flowering and fruiting. *Masala* seed is collected in December-January by climbing the trees and cutting a few fruiting branches. The best time for collection is when the capsules start to open up. The species hybridizes with other *Eucalyptus* species, therefore only seed from the well-identified seed trees within stands should be collected and not from isolated trees. The capsules are dried in the sun on sheets of paper to collect seed easily when the capsules open. Twigs and capsules are removed by sieving them from the seed. It is not worth the effort to try to remove the smaller debris from the seed.

Storage

Seed is stored in airtight containers and kept in a cool and dark place to preserve viability. Seed can be stored up to 1-3 years.

Pre-treatment of seed

Seed is soaked in warm water of 35-40 degrees Celsius for 5-10 minutes, and then put in cold water for 6-12 hours. After that the seed are placed in bags in airtight containers and covered with a plastic lit. This is repeated for 2-3 days until seed germinate. Seed soaked in water for 24 hours can also give good results.

Seed sowing in the beds

Seed mixed with sand is broadcasted on raised primary beds in Feb-March with a cover of fine sand. The bed is covered with hay. Germination takes place with 5 to 15 days. When they are 5 to 14 cm tall, they are pricked out to the poly bags.

Seed Biology

No. of seeds per kg.	Purity percent	Moisture percentage	Germination percentage	No. of seedlings per Kg. of seed	Time for germination in days
1,00,000	75	10	90	60,000 to 80,000	3 to 7

Soil preparation for the poly- pots and beds

The soil in the sowing beds and polythene bags should consist of 80% forest soil mixed with sand, 20% animal manure and 1% artificial fertilizer. About 10% coconuts husks can be added to the mix improve root growth of the seedlings. *Mycorrhiza* fungi may be needed for optimal growth of the seedlings and can be collected from the soil near older *Masala* trees and added to the potting mix.

Seed sowing in the tray for transplanting

Under a roof, seeds are sown in germination tray at the rate of 8-10 gram seed /1 m^2 in December. Since the Eucalyptus seeds are very tiny, they are mixed with fine sand and broadcasted and covered with sand again enough to cover the seed or pepper pot can be sued for broadcasting seeds as shown in figure 2. Then a flat piece of wood is used to press the surface. The tray is covered with a mulch of grass to protect the small *Masala* seed against larger water droplets. Important is to keep the small seed well watered to prevent drying out. Since the tiny seed like this is difficult to raise in nursery beds directly, it is recommended to go for germination tray.

Figure 2: Method of tiny seed sowing by using pepper and salt pot

Construction of germination tray

The germination tray can be made up of wood, metal or locally available materials like cartoon boxes. The tray is filled with soils, sand, straw and small pebbles at different layers. The bottom layer is filled with pebbles to ease drainage. The mid-layer is done with straw to maintain heat in the tray required for germination and the upper layer is filled with sieved soils and fine sand, where seeds are broadcasted. Overhead shed is provided to control excessive evaporation due to the direct sun light as shown in the figure 4. A wooden or metal stand is given to the germination tray to avoid direct contact with the ground surface (Figure 3).

Container size

Polythene bags of 3/5 x 7 inches can be used to raise seedlings

Transplanting

After 7-21 days or when the seedlings are 2-3 cm tall, have developed 2 pairs of leaves and a primary root of 1-2 cm long, they can be transplanted into polythene bags (Figures 3 & 4). Delays in germination and poor germination of the seed are often caused by sowing the seed too deep or by allowing the seed to dry out too much.

Figure 3: Pricking out the *Masala* seedlings for transplanting.

Figure 4: Transplanting *Masala* Seedlings into poly-bags

Fertilizer application

During the first 3 months 10 gram fertilizer NPK 15-15-15 is applied per seedling and a second application of 10-20 gram NPK 16-20-00, 2-4 weeks before planting the seedlings out.

Watering

Regular watering is necessary but water logging should be avoided to prevent the nursery from damping off. Watering is carried out either in the morning or in the evening. Being very small in size, *Masala* seeds may accumulate a place in a tray because of improper and heavy watering before germination and that may result into poor germination.

Weeding

Manual weeding needs to be carried out once a month to decrease growth competition for the seedlings.

Root pruning

Root pruning should be done after 2 months and before planting the seedlings out. All the roots growing out of the containers should be cut with seccateurs (Figure 5).

Figure 5: Root pruning

Hardening off

Hardening off can be done by removing the shade net after the seedlings are 2 months in the nursery.

Shade and shelter

About 70% of sunlight is required for this species. Protecting against heavy rain is not necessary.

Insects and fungi

No insect or fungi attack has been reported. However, Eucalyptus seedling is susceptible to various fungi causing damping-off and leaf diseases. When this happens, the infected parts of the seedlings should be removed manually (by hand).

11. Establishment of plantation

Site preparation

Site preparation should be carried out in February-March by plowing and digging of planting holes. A firebreak is made with 4–6 m wide strips by plowing, digging and controlled burning. Fencing is required to protect the seedlings against cattle.

Planting season

The time of planting is in June or July with seedlings of 0.40-0.50 m tall, and a root-collar of 0.3-0.5 cm in diameter. During transportation of the seedlings to the planting site they should be covered by shade nets to prevent overheating and drying out.

Fertilizer application

Artificial or natural fertilization is both recommended depending on the soil conditions. Per seedling, 10 gram of fertilizer NPK 15-15-15 is applied after 1 month. A second application of 50 gram is given after 3 months and sometimes another 100 gram just before the dry season. Fertilizer should be applied in a circle of 0.5 m around the seedlings. In case of planting on slopes, a hole of 0.20-0.30 m above the seedling is dug and the fertilizer is applied.

Replacement planting

Replacement planting can be done after 2 weeks.

Weeding

In the first year weeding should be carried out after 1 month, 3 months and again at the end of the rainy season. In the second and third year weeding should be done in August- September. Weeding is important because *Masala* requires full sunlight. Weeded material can be placed around seedlings as mulch to conserve soil moisture.

Diseases and pest

Insects such as termites and aphids and rodents may be troublesome to the tree, and both physical and chemical measures are used to control them. Young trees and those weakened by drought can be badly infected by moth larvae, eucalyptus snout beetle, termites and eucalyptus borer.

Thinning

Thinning is needed when the canopy closes, often after 3-8 years. The rotation period can vary from 5-30 years. Diameters of 0.5 m can be attained within 30-35 years, if planted out at a spacing of 2 x 3 m and thinned to a final stocking of 300 stems per hectare. Coppice management is possible with 2-3 rotations. Before the dry season the shed leaves must be removed and burned as they attract fire because of to their high oil content.

12. Uses

The wood is used for general construction and decoration, chopping boards, ply-boards, firewood, charcoal, furniture, pulp and packaging. The gum from the stem can be used as a dye. A tonic from bark and roots is used in medicine. The flowers can produce quality honey. It is widely planted in agro-forestry systems. In the *Bhawar* region, *Masala* has high potential of being sustainable source of poles required for electricity. It can be harvested within 4 to 6 years of plantation, a very short rotation.

Red gum is so named for its brilliant red wood, which can range from a light pink through to almost black, depending on the age and weathering. It is somewhat brittle and is often cross-grained, making hand working difficult. Traditionally used in rot resistant applications like stumps, fence posts and sleepers, more recently it has been recognized in craft furniture for its spectacular deep red color and typical fiddle-back figure. It needs careful selection as it tends to be quite reactive to changes in humidity (moves about a lot in service). It is quite hard, dense (about 900 kg/m^3) and can

take a fine polish and carves well. It is a popular timber for wood turners, particularly if old and well-seasoned. It is also popular for use as firewood.

B. Growth performance

1. Study design and methods

1.1 Study area description

Data presented in the book were collected from the central development region of Nepal, *Dhanusha* district, the project area of Nepal Agroforestry Foundation (NAF), where NAF has been working for 15 years for promoting private forestry in the district. The study covered nine VDCs of the district, where farmers have established stands of *Masala* of different age ranging from year 2 to 10 years old. The geography of the area is very fragile and soil is sandy and hence the water holding capacity of the area is very low.

1.2 Sample size and sampling intensity

Stands with at least 5 *Kathas* (30 *Kathas* = 1 hectare) were taken into consideration for the study. Two major variables were measured: DBH and Height. Data were collected from the stands aged 2, 5 and 10. There were altogether 9 stands measured (3 replications). Site quality has been assumed to be the same in each stand. Since the stands are from the same source i.e. NAF's nursery, author assumes that the stand performs the similar growth pattern. The sampling size (unit) was 5*5 m^2 with 2 % sampling intensity. The sampling units were randomly selected. Based on the data from the sample plots, Current Annual Increment (CAI) was calculated and a table was developed which gives the possible DBH and height for each age from 2 to 10.

In case of bund plantation, individual tree was considered as sampling unit and the first one was selected randomly and rest was selected systematically i.e. every third tree. Therefore, the method selected for the bund was systematic sampling with random start.

2. Findings

2.1 Growth performance in the bund and the stand (Based on average diameter)

The average diameter of the 2 years old plantation is 3.84 cm and 5.99 cm in stand and bund respectively (table 1). Even though the CAI of the two plantation pattern does not vary, the initial growth is higher in case of the bund plantation, and thus the bund crop reaches a harvestable size one and half years before the stand crop is ready. The growth rate varies with the plantation pattern (Table 2). The S/B ratio clearly indicates that bund plantation performs better than the stand plantation (Table 1).

Table1: Growth pattern over time in DBH (cm)

Pattern	Age (Years)								
	2	3	4	5	6	7	8	9	10
Stand	3.84	7.57	9.35	10.35	11.76	13.7	15.72	17.70	19.68
Bund	5.99	9.71	11.8	12.33	14.44	16.6	18.7	20.78	22.9
S/B ratio	0.64	0.78	0.79	0.84	0.81	0.83	0.84	0.85	0.86

Source: Fiend Survey, 2007

Table 2: Growth performance in the stand and bund plantation

Pattern		**Age class**	
Stand	**Parameters**	**2 to 6**	**6 to 10**
	CAI	1.98	1.98
	Increment percent	25.4	12.6
Bund	CAI	2.11	2.12
	Increment percent	20.7	11.3

Source: Fiend Survey, 2007

2.2 Growth performance in the bund and the stand (Based on maximum diameter)

The maximum diameter attained by the individual plant in stand and bund at the age of 10 is 36.2 and 45.1 cm respectively. But in the early age the difference is not so vast. In the initial age, the growth pattern goes in similar way until 4 years. The growth pattern changes abruptly after 4, making a difference of about 9 cm at the age of 10. Assuming the constant increase in growth till 10 based on the CAI of six years old stand and bund crops, the following growth has been projected. The growth rate decreases more rapidly in the bund than in the stand. In the bund plantation, the 36 cm diameter reaches at the age of 8 while it requires 10 years to reach that diameter for the stand crops (Table 3 and Table 4).

Table 3: Growth pattern over time in DBH (cm)

Pattern	**Age (Years)**								
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bund	8.5	15	18.6	23.2	26.8	31.4	36	40.5	45.1
Stand	8	14.5	17.8	20.8	22.1	25.6	29.2	32.7	36.2
S/B ratio	0.94	0.97	0.96	0.90	0.82	0.82	0.81	0.81	0.80

Source: Fiend Survey, 2007

Table 4: Growth performance in the stand and bund plantation

Pattern		**Age class**	
Stand	**Parameters**	**2 to 6**	**6 to 10**
	CAI	3.5	3.5
	Increment percent	23.4	12.1
Bund	CAI	4.5	4.5
	Increment percent	25.9	12.7

Source: Fiend Survey, 2007

2.3 Productivity of the stand and bund

The 10 year stand plantation produces 50.7 m^2 and 1397.1 m^2 respectively based on average and maximum diameter attained by the crop at that age (table 5 & 6). Similarly a 100 meter long bund will produce 4.2 and 161.3 BA respectively at the age of 10. The ratio of productivity between the bund (in 100 meters) and the stand (hectare) indicates that the difference in productivity decreases with time. To achieve 50.7 BA in 10 years, about 50.7/4.2 (12) bunds of 100 meter long is required. Hence, a 1200 meter long bund produces the Basal Area (BA) equal to the one hectare stand in 10 years (Table 5).

Table 5: Productivity of a stand and a bund in terms of basal area (m^2) - *Average diameter*

Pattern	Parameters	Age (years)									Spacing	Density
		2	3	4	5	6	7	8	9	10		
Bund (B)	BA/tree	0.003	0.007	0.011	0.012	0.016	0.022	0.027	0.034	0.041		
	BA/100m	0.3	0.7	1.1	1.2	1.7	2.2	2.8	3.4	4.2	1m	101
Stand (S)	BA/tree	0.001	0.004	0.007	0.008	0.011	0.015	0.019	0.025	0.030		
	BA/Ha	1.9	7.5	11.4	14.0	18.1	24.7	32.3	41.0	50.7	2*3	1667
	Ratio B/S	0.16	0.09	0.10	0.09	0.09	0.09	0.09	0.08	0.08		

Source: Fiend Survey, 2007

Table 6: Productivity of a stand and a bund in terms of basal area (m^2) –*Maximum diameter*

Pattern	Parameters	Age (years)									Spacing	Density
		2	3	4	5	6	7	8	9	10		
Bund (B)	BA/tree	0.057	0.177	0.272	0.423	0.564	0.774	1.017	0.016	1.597		
	BA/100m	5.7	17.8	27.4	42.7	56.9	78.2	102.8	130.0	161.3	1m	101
Stand (S)	BA/tree	0.01	0.17	0.28	0.34	0.38	0.51	0.52	0.67	0.84		
	BA/Ha	8.4	275.1	472.4	566.2	639.1	16.3	859.3	1111.9	1397.1	$(2*3)m^2$	1667
	Ratio B/S	0.68	0.06	0.06	0.08	0.09	0.09	0.12	0.12	0.12		

Source: Fiend Survey, 2007

C. Economics and trade

1. Introduction

The general mode of trade for timber, poles and fuel-wood is basically contractor-based. The local contractors collect wood (timber and poles especially) from the private tree growers and sells them either in the local market i.e. saw mill owners or directly transport to the big city centers like *Kathmandu*, *Pokhara* and *Narayanghat* and *Janakpurdham*. Besides, some farmer-led organization has also taken initiatives for marketing and trade of their forest products. For example, the Terai Private Forest Development Association (TPFDA) in *Dhanusha* district, which is supported by Nepal Agroforestry Foundation (NAF), is engaged in timber and pole marketing to avoid the contractor based marketing channel for the benefits of private tree growers.

2. Methods of market study

This study only covered the local level market of the timber. For this, author had selected only five saw mills out of 20 currently running within the project area. The purpose of saw mill survey was to find out the size of timber in demand in local market and trend of price of timber over time according to its size. The price of each species for each size from 2002 to 2007 has been collected and presented in the table 8.

3. Market value

The eucalyptus has a high value as a timber as well as poles. Comparatively farmers prefer to produce poles rather than producing bigger size timber since poles are in higher demand due increased rural electrification program of the government. Plywood factory at the local market is another option for farmers as a secured market but the rate set by the factory is far below what they get by selling same volume as a pole (Table 7 and Table 8).

4. Marketable size

The size varies with purpose of use. For pole, the girth at stump height and at the top should be 22 inch and 14 inch respectively. For timber purposes, the product is ready to harvest once it attains the girth of 2 feet. The saw-mill runners at the local market don't consider the length while determining the rate. It is only the girth that determines the price (Table 8).

5. Market price scenario over time

In the last six years, there has been no change in market price of eucalyptus wood. If we apply the general principle that the value of money decreases over time, investing capital in eucalyptus plantation for timber is no more a business of profit.

Table 7: Market price of Eucalyptus wood in local plywood factory

Size (Length and girth)	Rate/cu ft
4 ft *30 inch	NRs. 85
4 ft * >30 inch	NRs. 150

Source: Field survey, 2007

Table 8: Market price of the Eucalyptus wood in local sawmills

Dimension							Year					
Girth (ft)	**DBH (ft)**	**DBH (inch)**	**DBH (cm)**	**<, >**	**L (ft)**	**Rate /Cft**	2002	2003	2004	2005	2006	2007
2	0.6	7.6	19.4			**80**	**80**	**80**	**80**	**80**	**80**	**80**
3	1.0	11.5	29.1			140	140	140	140	140	140	140
4	1.3	15.3	38.8			160	160	160	160	160	160	160
8	2.5	30.6	77.7			200				200	200	200

Source: Field Survey, 2007

6. B/C ratio and rotation period

The crop will reach pole size at the age of 4 based on the maximum diameter (Table 10). The Mean annual Increment (MAI) is 150m^3/ha/year at this rotation (Table 10). Based on the various literatures, the merchantable length of the tree is the 2/3rd of the total height. The crop reaches 10.8 m at this age, which is 1.8 meter bigger than the required length for the poles. About 3000 meter (1.8m *1667) left in a hectare can be used as firewood. Taking the top girth (14" = 11.3 cm in diameter) of a pole as a reference to calculate the volume of the left wood, the volume of the 1.8m meter long log will be: (3.14* D^2* h)/4 = 0.018 m^3 . The total volume will be (3000*0.018 = 54 m^3).The standard size of a *chatta* is (1.52*1.52*1.52 = 3.5 m^3). Hence, about 15 *chattas* (54/3.5) of firewood can be collected from a 4 –year- old stand raised for the pole production and this excludes the volume of branches.

Table 9: Benefit-cost analysis of Eucalyptus plantation in a 4-year rotation

Area: 5 *Katha*				**Age of the stand (in year)**			
				1	2	3	4
Costs							
Items	**Man days**	**Rate**	**Total**				
1.Land preparation	2	100	200	200			
2.Pitting	8	100	800	800			
3.Seedling cost	300	1.5	450	450			
4.Seedling transportation			350	350			
5.Plantation	4	100	400	400			
6.Weeding	4	100	400	400	200	200	
7.Pest and Disease control				300	300	300	300
8.Fencing				10000			
9. Opportunity cost (cereal and cash crop)							
Net income from Millet							
Net income from Sugarcane				8800	8800	12000	12000
Net income from Vegetable							
10. Final felling cost	70	100	7000				7000
Total cost (year wise)				**21700**	**9300**	**12500**	**19300**
Present value (PV) with 15% discount rate				**19700**	**8087.0**	**9451.8**	**12690.1**
Total PV		**49928.8**					
Benefits							
1.Income from intercropping							
Vegetable				3200	3200		
Sugarcane							
Millet/Maize							
2.Income from final felling (277*800)					3200		**221600.0**
Total benefits (year wise)				**3200**	**3200**		**221600.0**
Present Value PV				**3200**	**2783**		**145705.6**
Total PV		**151688.2**					
Net Present value (NPV) = (Total Benefits-total Costs)		**101759.4**					
B/C ratio		**3.0**					

Source: Field Survey, 2007

Table 10: Year-wise productivity of the stand

Age	Avg. Height (m)	Avg. dia. (cm)	H/D	Max. height (m)	Max. diameter(cm)	H/D	Marketable length(m)		Density/ha	Avg. log volume (m^3)		total volume/ha		MAI M^3/ha/yr
							Avg.	Max.	$(3*2)m^2$	Average	Maximum	Average	Maximum	
2	5.02	3.84	1.31	8.8	8	1.1	3.35	5.9						
3	9.14	8.61	1.06	11.5	14.5	0.8	6.09	7.7			0.16		266.7	88.9
4	12	9.35	1.28	16.2	19	0.9	8.00	10.8			0.36		600.1	150.0
5	15.8	10.35	1.53	20.5	20.8	1.0	10.53	13.7			0.43		716.8	143.4
6	17.3	11.76	1.47	24.2	22.1	1.1	11.53	16.1		0.13	0.56	223.4	930.2	155.0
7	20.20	13.7	1.47	24.8	25.6	1.0	13.47	16.6		0.19	0.79	321.7	1321.9	188.8
8	23.11	15.72	1.47	28.3	29.2	1.0	15.41	18.9		0.40	1.23	658.5	2050.4	256.3
9	26.02	17.70	1.47	31.7	32.7	1.0	17.35	21.1		0.43	1.46	723.5	2433.8	270.4
10	28.93	19.68	1.47	35.1	36.2	1.0	19.29	23.4		0.59	2.05	988.5	3417.4	341.7

Source: Field Survey, 2007
Note: H/D= Height-diameter ratio

D. Photo plates

Eucalyptus mature fruit

		
Eucalyptus leaf	Eucalyptus Flower	Eucalyptus form
		
Eucalyptus seeds	Inflorescence	Immature fruit

Eucalyptus planted in the bund

Private tree grower carrying out weeding in the Eucalyptus nursery

Eucalyptus flower

Teak
(Verbenaceae)
Sagwan

A. Silviculture

1. Scientific classification

Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Lamiales
Family:	Verbenaceae
Genus:	Tectona
Scientific Name:	*T. grandis* Linn.
Local name:	*Sagwan, Teak, Sagon*
English Name:	Teak

2. General introduction

Sagwan or Teak *(Tectona grandis)* is a tall and handsome deciduous tree, losing all their leaves for much of the dry season. It is a fast growing species. It has several local names: *Sagwan, sagon, saigon, saj, taku, kayum* etc in local languages. Leaves are shed in the dry season. Teak is a light-demanding tree and grows in mixed deciduous forests with *Xylia xylocarpa, Lagerstroemia* spp., *Afzelia xylocar*, *Pterocarpus macrocar* and bamboo. Teak tree has distinct annual growth rings. It grows quickly in the right conditions and puts on nearly one inch of growth in diameter in four to five years. It can grow up to a height of 45 m and a girth of about 4 to 5 m in nearly 100 years when its wood is considered fully mature and suitable for any use where along with strength, good looks of the finished product are the main requirement. Teak is a strong light demander, intolerant of shade and requiring complete overhead light. It can tolerate drought, fire and wind.

The height of the tree at the moment of first flowering is important in silviculture. When it is long (it may reach up to 10 m), the final bole form is positively affected, but early-flowering trees may develop extremely wide crowns and short boles. The time of the first inflorescence is determined by both genetic and environmental factors.

3. Geographic distribution

Teak occurs naturally in parts of India, Myanmar, Lao PDR and Thailand and it is naturalized in Java, where it was probably introduced some 400-600 years ago. It has been widely established in plantations as an exotic species for producing high quality poles and timber outside the countries of its natural distribution. The earliest plantation of teak, apart from Java, has been traced back to 1680 when a Dutchman, Van Rhede successfully introduced it to Sri Lanka. Teak planting in India began in the1840s but major planting took off from 1865 onwards. In Myanmar and Indonesia, teak plantations using the "*Taungya*" method were initiated in 1856 and around 1880 respectively.

Teak is not native to South and south East Asia (Bangladesh, Cambodia, Nepal, Pakistan, Japan, Sri Lanka, Taiwan, Vietnam), Pacific (Australia, Fiji Islands, U.S. Pacific Islands), East Africa (Kenya, Malawi, Somalia, Sudan, Tanzania, Uganda, Zimbabwe), and West Africa (Benin, Ghana, Guinea,

Ivory Coast, Nigeria, Senegal, Togo). It was introduced during 50's as a "T*aungya*" plantation in Nepal and is being practiced in *Neejgarth* and *Tamagadi* area of the terai.

4. Morphology

Stems

Sagwan tree has an erect trunk, a cylindrical bole and an umbrella like beautiful crown. It tends to be fluted at the base. Heartwood is dark golden yellow. Basic specific gravity (oven dry weight/green volume) of teak wood is 0.55

Leaves

Leaves are simple, opposite, large (30 to 50 cm x 25 cm), round, broad, pointed, broadly elliptical or obovate, acute or acuminate, coriaceous, possessing minute red glandular dots and thick in structure. New leaves appear in May-June.

Flowers

Teak flowers are branched and 50 to 100 cm long whitish cymes. Individual florets are small and round with diameter of about 4 mm. Flowers are many, small, having pleasant smell, in large erect terminal branched tomentose cymose bladder like calyx.

Barks

Its bark is thin, fibrous and light brown or gray in color peeling off in long thin strips.

Fruits/seeds

The fruit is a hard, irregularly rounded drupe. It varies in size from 5-20 mm, the most common size being between 11 and 17 mm. Its structure consists of a thin papery outer layer (the persistent calyx), a thick corky middle layer (mesocarp) and a stony inner part (endocarp) which contains the 4 seed chambers. Number of fruits per kg varies around 1100-3500 with an average of approx. 2000 fruits/kg. This corresponds to approx. 500 fruits per liter.

The seeds are oval and about 6 x 4 mm. Only rarely have all 4 seed chambers fully developed seeds, the normal number being 1-2. Usually only one seed per fruit manages to develop into a seedling.

5. Phenology

Reproduction Ecology

T. grandis is 96-100% self-incompatible. The species is hermaphroditic. Fruits mature about 4 months after fertilization. Premature shedding of fruit is a problem. Up to 60% fruit set has been reported following cross-pollination of teak. The individual flower has a 1-day cycle; optimum pollination period is between 1130 h and 1300 h.

Blooming and fruiting ecology

White flowers in large terminal tri-chotomous panicles appear in May-August. Teak normally starts to flower 6-8 years after planting. However, trees have been observed to flower at the age of 3 months while a few specimens of superior phenotype did not flower until the age of 27 years. Trees tend to flower synchronously and only a few flowers (about 1%) develop into fruits. Flowering takes place in the rainy season, starting about one month after the first rains. Teak usually flowers every year but with large variation in intensity between years. Pollination is by insects. Sometimes flower and fruit setting is greatly disturbed by defoliating insects which also eat the flower buds. The fruit attains its full size in approximately 50 days, but it is not mature until 120-150 days after fertilization. A sign of maturity is that fruits can be shaken from the tree, or fall to the ground naturally.

Pollination ecology

Pollination takes by help of insects such as black ants, horse flies, and particularly by bees (bumble bees, bees and wasps), and occasionally by wind too. Fruits develop to full size about 50 days after pollination.

Fruiting season

The fruit appear in August-September and ripen between November and January. The seeds are small and take considerable time to germinate.

Dispersal ecology

Fruit is enclosed in an inflated dry calyx, which assists in the wind dispersal. During rainy season, the calyx helps the fruits float on water and disperse further.

Seed viability

Fruits are collected off the clear ground under the trees. Seeds can be stored in gunny bags for at least two years without loss of viability. Seeds stored for a year germinate better than fresh seeds.

Propagation ecology

New plants can be propagated by seed, cuttings, suckers, grafting and tissue culture.

6. Habitat/ecology

Climate

Teak grows up to 1,000 m altitude. Annual rainfall is about 1,200-3,800 mm with a dry season of up to 6months. Mean annual temperature is about 18-25 degrees Celsius. It is not frost tolerant. It prefers deep well-drained loamy soils, but can come up on a variety of soils.

Soil

Teak prefers deep and fertile loamy-sandy soil with good drainage.

7. Patterns of plantation

Pattern

In case of Teak, stand plantation is very common among farmers. Bund plantation is also seen at some places but not as extensive as eucalyptus. The bund plantation requires no land specially allocated as seedlings are planted along the bund of the cultivated field. Teak is not as much liked as other species i.e. Eucalyptus, *Khamari*. Farmers also plant this species in a scattered manner wherever land is available.

Spacing

In case of the scattered plantation, there is no definite spacing and it is based on the space available while in case of stand, three different spacing systems are in practice i.e. 3*2 m^2 , 2*2 m^2, 3*3 m^2. Spacing varies with objectives of the plantation. When objective is to produce fuel-wood and plywood, narrow spacing is preferred to the wider one. For timber, obviously the preferred spacing would be the wider one.

8. Nursery techniques

Seed collection

Teak can be collected from December-April. Best is to collect the last fruits from well-formed trees older than 20 years. One has to wait until the fruits turn from green to light-brown and fall down to the ground. Sometimes it is necessary to climb up the trees to collect seed. Teak fruits are usually collected from the ground. In seed source areas, the ground is usually cleaned and sometimes burnt to prepare seed collection. To ease collection, a cover can be spread out on the ground. The fruits fall over a period of 3-4 months in the dry season. Seed collection should be done at least twice in a season, so that early fallen fruits do not remain on the forest floor for long. The amount of fruits which can be collected depends on age of stand, location and type of stand and it is difficult to give exact figures about seed production. Generally, seed production is in the order of 20-30 kg/ha/year in plantations and seed production areas with low management, whereas in seed orchards with more intensive management seed production may be as high as 200-300 kg/ha/year.

Processing and handling

After collection, the fruits are cleaned for branches, leaves and rotten and damaged fruits and then dried in the sun for 2-3 days. After drying, the calyx is removed in a cement mixer, seed thresher or by squeezing and beating the seed in a bag as shown in figure 1. Finally the impurities are removed by winnowing.

Figure 1: Removing the fruit covers by beating the fruits in a bag with a stick

Storage

Teak seed stores well and may keep its germination capacity for several years provided the seed has low moisture content before storage and is protected against fluctuations in temperature and humidity during storage. If seeds are to be used in the same planting season, no special storage is needed. Seed can be piled in a convenient place near the nursery, preferably in a shed or in a storeroom, but not necessarily dried. Seed can be stored this way for maximum 3-4 months. Seed can be stored for up to two years at around 12 % moisture content and stored in airtight containers (glass jars or sealed plastic bags) and kept in a dry, shaded and relatively cool place. If stored at low moisture content and in a cold store (0-4°C), the germination capacity of the seed can be maintained for 5-10 years.

Pre-treatment of seed

Germination of teak is often poor and sporadic but the exact nature of dormancy is not known. The most common method is soaking and drying method. In this method, Teak fruits are soaked in water during the night, and dried during the day in the sun. This is repeated for 1 week. Teak fruits from dry areas are more difficult to germinate. When necessary repeated soaking and drying can continue for a second week. Germination begins 18 days after sowing, increases for 15 days, and gradually decreases.

Sometimes fruits are exposed to ants for 1-2 weeks to remove the fruit covers and hasten the germination.

Inoculating teak seeds with *Scytalidium* sp., a cellulolytic fungus isolated from teak litter and keeping them moist for 21 days results in 96-percent germination compared to 20-percent for un-inoculated controls.

Chemical treatment can be applied to accelerate germination. Treating with indoleacetic acid and gibberellic acid, alone and in combination at various concentrations, increases germination 5 to 12 percent over controls. Simply storing seeds for several months also improves germination.

Seed Biology

No. of fruits per Kg.	Moisture percentage	Germination percentage	No. of seedlings per Kg. of seed
1,850 to 3,100	7.8	10 to 15	650

Seed sowing in the beds

Pretreated seeds are put in big primary beds in April-May, just before raining season and covered lightly with forest soil. Sometimes 1 cm of sand, sawdust or rice husks is used instead to cover the seed and beds are watered copiously every day. Germination takes place in 10 to 20 days. During next rainy season, plants are uprooted and stumps are prepared which are planted in field in crow-bar holes. The stump plants are grown in the nursery until they reach 1.2 to 2.5 cm in diameter at the root collar; the top is cut back to about 2.5 cm, and the tap root cut back to 18 or 20 cm in length

Soil preparation for the container

Soil mixture for potting should contain 1 part sand and 2 parts forest top soil.

Container size

Polythene bags of 3/5 x 7 inches are suitable to raise Teak seedlings.

Seed sowing in poly-bags

Direct sowing in containers of up to 3 fruits per container is also possible. From 1 fruit 2-3 seedlings can develop but only 1 seedling should be kept in a container. Another method of raising seedlings is to directly broadcast in nursery beds and transplant them later in the containers. The seed beds need to be covered with 1.2 to 2.5 cm of sand, soil, or sawdust. A temperature of 30 °C during germination appears to be optimal for the seeds. A seedling yield of about 25 percent can be expected from good seed. Germination is variable, but when teak seedlings have developed the first pair of leaves the seedlings are transplanted into containers (Figure 2). Young seedlings must be removed carefully from the seed bed and watered very often until they are well established into the pots. Newly transplanted seedlings are kept in 50-70% shade.

Figure 2: Transplanting of *teak* seedling into the polybags

Watering

Both the containers and seed beds should be kept moist. Once the seedlings have become established in containers, gradual decrease in watering is suggested. To prevent damage from water droplets, sprinklers are recommended for watering the newly transplanted tender seedlings.

Fertilizer application

Manure, burned rice husk and sawdust can be added to improve soil quality and drainage and also in reducing weight of the container. NPK fertilizer can also be applied to stimulate seedling growth when necessary.

Weeding

Weeds should be removed by hand from the pots to avoid nutrient competition with the seedlings. Weeding should be done regularly.

Root pruning

Teak seedlings are kept in the nursery for about 15 months so root pruning is needed, by cutting the roots growing out of the bag (Figure 3). Frequently moving the pots around, or by placing the pots on a plastic sheet or concrete floor limits roots penetration into the soil.

Figure 3: Root pruning technique

Hardening off

Hardening off can be done by removing the shade net 1-2 months before planting the seedlings out. During this period watering is also gradually reduced. Seedlings should be transported to the planting site with care to avoid damage to the seedlings.

Insects and fungi

Attacks by fungi, bacteria and insects may give problems. Good water drainage is necessary to avoid root damages. By monitoring often and removing affected seedlings and insects manually much damage can be limited.

9. Establishment of plantation

Teak is usually planted by seeds which are directly planted in the field, by seedling raised in pots or by using stumps.

Plantation by seed/seedlings

Planting with direct seedling is conducted usually on October (at the beginning of dry season) or being conducted before the first rain come, when soil temperature is still hot. Teak seeds are planted at 2 cm depth (below the soil surface) and are afterwards covered with fine soil. On each planting point, 4 teak seeds are planted to get the opportunity to obtain best seedling. Similarly poly-pots seedlings are frequently used in teak plantation. The poly-pots are removed at the time of plantation in June-July.

Plantation by stumps

Planting of stumps is an effective and economical method for Teak. Stumps are seedlings that have their roots pruned to 15 cm, and the stem cut 1-2 cm above the root-collar. A suitable size of a stump

for field planting is 1 to 1.5 cm in diameter at the root-collar. To prepare stumps the seedlings must be left to grow in the nursery bed for at least 1 year, then they are lifted and the root-shoot cut as stumps. Smaller seedlings remain in containers to produce ordinary seedlings. Stumps should be prepared during the dry season and can be kept up to 1-3 months in a cool hole in dry sand. Freshly prepared stumps can be planted out directly but they are less viable than stored stumps.

Site preparation

The planting area should be cleared of weeds and other debris. Therefore plowing the whole area before planting is recommended. Manual weeding has to be done before planting. The cut weeds can later be used as mulch around the plants. Although teak tolerates low intensity forest fires, large fires kill the young plants. A firebreak of 10 m wide by plowing or controlled burning should be made around the planted area during the dry season. Keeping the plantation clear of weed and debris is the best way to prevent fire. In some areas it is important to make fences around the plantation to prevent cattle from damaging the trees or causing erosion.

Fertilizer application

The stump will start to sprout after about 1 week. After 1-2 months of planting, once during the rainy season and at the beginning of the dry season per seedling 25-50 gram fertilizer NPK 15-15-15 or 22-11-11 is applied. In the second year 50-100 gram and in the third year 75-150 gram per seedling is applied. Sometimes in year 4-5another 100-200 gram is given. Weeding is important and is done manually at the same time as fertilizing.

Replacement planting

Replanting is done as soon as possible, sometimes even in the second year.

Insects and pest

Some insects attack teak trees, such as leaf defoliators, leaf skeletonisers, stem borers and bee-hole borers (Table 1). They can be controlled manually by destroying the feeding larvae or caterpillars; some need specialized insecticides or bacteria to control them.

Table 1: Pest insects recorded from intensively managed Teak plantations

Pest species (order/family)	**Nature of damage**	**Pest status**
Hyblaea puera (Lepidoptera: Hyblaeidae)	Defoliator	Major, already known
Eutectona machaeralis (Lepidoptera: Pyralidae)	Leaf feeding	Major, already known
Sahyadrassus malabaricus (Lepidoptera: Hepialidae)	Stem boring	Major, already known
Mealy bugs (Hemiptera)	Leaf feeding	Minor
Planococcus sp. (Hemiptera: Pseudococcidae)	Leaf feeding	Minor
Zeuzera coffeae (Lepidoptera: Cossidae)	Stem boring	Minor, but emerging problem
Helicoverpa armigera (Lepidoptera: Noctuidae)	Leaf feeding/ terminal shoot	Major, recently recorded

	damage	
Dihammus sp. (Coleoptera: Cerambycidae)	Stem boring	Minor, but emerging problem
Aleurodicus sp. (Homoptera: Aleurodidae)	Leaf feeding	Minor

Thinning

Thinning takes place every 4-5 years or when the canopy closes. The rotation period is about 20–50 years. Coppicing is good with a rotation possible of 10-20 years. Stump plants (seedlings with the tops removed) or potted plants grown in plastic nursery bags are usually used in field plantings. Under selection system, the following size is removed at every thinning carried at an interval of 5 years (Table 2).

Table 2: Thinning schedule for a 30- year rotation

Sn.	Description	DBH of removable stems	Age of the stand (years)
1.	First thinning	< 5 cm	5
2.	Second thinning	< 15 cm	10
3.	Third thinning	< 20 cm	15
4.	Fourth thinning	< 25 cm	20
6.	Fifth thinning	< 30 cm	25
7.	Final harvest	>30 cm	30

10. Intercropping

Farmers prefer intercropping for the first two years of teak plantation. Mostly farmers grow lentil, linseed, mustard, maize, reddish, eggplant, pigeon pea and tomato as inter-crops. Intercropping not only uses the free space but also helps add organic material to the main crop because the crop residues (straw, leaves, etc) are left unattended to decompose for the benefits of the main crop. The cropping pattern in the teak plantation is given below in the table 3.

Table 3: Intercropping in the Teak Plantation

Name of the crop	Moths												year
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Lentil	■	■	■						■	■	■	■	First year
Linseed	■	■	■						■	■	■	■	
Mustard	■								■	■	■	■	
Maize				■	■	■	■	■					Second year
Reddish				■	■								
Egg Plant				■	■	■	■	■					
Tomato				■	■	■							
Lentil	■	■	■						■	■	■	■	
Linseed	■	■	■						■	■	■	■	
Pigeon pea	■	■	■				■	■	■	■	■	■	

Source: Field Survey, 2007

11. Uses

Teak is famous for its valuable construction, shipping decks and furniture wood (Figure 4 & 5) and is widely planted in small stands in agroforestry systems. The bark and young leaves are used for dye. Teak wood is also used in local medicine. Teak is best for plywood production.

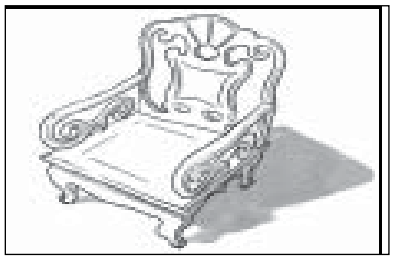


Figure 4: Teak wood is excellent for furniture.

Teak has many other uses in addition to being an excellent timber. Its wood contains a kind of scented oil which renders any box or wardrobe made therefore repellent to white ants and other insects. The leaves yield a kind of dye which is used locally in coloring clothes, edibles, etc. These are also used as packing material and for making cheap leaf cups and plates and poor peoples' umbrellas. The wood when hollowed exudes a kind of gum which is used in pan-masala. The juice of teak flowers is used for common cold. It whets appetite and relieves headache and acidity.

According to Ayurveda, wood is acrid, cooling, laxative, sedative to gravid uterus and useful in treatment of piles, leucoderma and dysentery. Flowers are acrid, bitter and dry and useful in bronchitis, biliousness, urinary discharges etc. Roots are useful in treatment of urinary system related troubles. According to *Unani* system of medicine, the oil from flower is hair promoter and useful in scabies. Wood is good for headache, biliousness, burning sensation and pain and liver related troubles. It allays thirst and possesses anthelmintic and expectorant properties.

Figure 5: Teak furniture

B. Growth performance

1. Study design and methods

1.1 Study area description

Data presented in the book were collected from the central development region of Nepal, *Dhanusha* district, the project area of Nepal Agroforestry Foundation (NAF), where NAF has been working for 15 years for promoting private forestry in the district. The study covered nine VDCs of the district, where farmers have established stands of *Masala,* of different age ranging from year 2 to 15 years old. The geography of the area is very fragile and soil is sandy and hence the water holding capacity of the area is very low.

1.2 Sample size and sampling intensity

Stands with at least 5 *Kathas* (30 *Kathas* = 1 hectare) were taken into consideration for the study. Two major variables were measured: DBH and Height. Data were collected from the stands aged 2, 7, 11 and 15. There were altogether 12 stands measured (3 replications). Site quality has been assumed to be the same in each stand. Since the stands are from the same source i.e. NAF's nursery, author assumes that the stand performs the similar growth pattern. The sampling size (unit) was 5*5 m^2 with 2 % sampling intensity. The sampling units were randomly selected. Based on the data from the sample plots, Current Annual Increment (CAI) was calculated and a table was developed which gives the possible DBH and height for each age from 2 to 15.

2. Findings

2.1 Growth performance in the stand

The Teak is slower in growth than *Sissoo* and Eucalyptus and hence takes longer time to get maturity and to reach the harvestable size for plywood and timber. It grows 0.98 cm annually in the *Bhawar* region of the *terai*. The growth is higher during 6 to 14 years. The increment percent is higher at 6 to 10. It decreases rapidly after 14 years (Table 4).

Table 4: Growth performance of the stand

	Age class				
Parameters	**2 to 6**	**6 to 10**	**10 to 14**	**14 to 18**	**18 to 25**
CAI	0.82	1.55	1.58	0.25	0.40
MAI (in twenty years):				**0 .98cm**	
Increment percent	12.2	13.6	8.92	1.17	1.72
Average growth/year in 25 years:				**7.53 %**	

Source: Fiend Survey, 2007

In the early age until 8, the ratio indicates that the standard deviation is higher as compared to the later age. Therefore the average will not estimate the yield close to the actual population yield. During 14 to 17 years, the ratio tends to be 1. That indicates that the growth tends to be distributing

proportionally in all trees at this age class. After 17, the variation starts increasing, which indicates the bigger trees tend to have a more rapid growth than the smaller ones (Table 5).

Table 5: Growth pattern over time in DBH (cm)

Based on average Diameter																							
Age (Years)																							
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
5.0	5.8	6.6	7.4	8.3	9.8	11.4	12.9	14.5	16.	17.6	19.2	20.8	21.0	21.3	21.5	21.8	22.2	22.6	23.	23.4	23.8	24.2	24.6
Based on the maximum diameter																							
8.7	10.6	2.6	14.6	16.6	17.5	18.5	19.5	20.5	21.2	22.	22.8	23.6	24.2	24.9	25.0	26.2	26.8	27.5	28.1	28.8	29.4	30.1	30.8
0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Source: Fiend Survey, 2007

Note: the last row is the Dia. (Average) to Dia (Maximum) ratio.

2.2 Productivity of the stand

Until the age of 10, the productivity varies greatly between the maximum and average, indicating that there is a high variation in growth among the individual trees. After 10, the variation decreases because the rate of growth of bigger trees slows down while the rate of smaller tress accelerates. And again after 23, the ratio starts decreasing because the smaller trees after getting considerable growth in this period might grow at a slower rate (Table 6).

Table 6: Productivity of a stand/hectare in basal area (BA) based on average and maximum diameter

BA/ha	**Age (years)**																							
	2	3	4	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	14	15	16	17	18	19	20	21	22	23	24	25
Avg.	3.3	4.5	5.8	7.3	9.0	12.7	17.0	21.9	27.5	33.8	40.8	48.4	56.6	58.0	59.4	60.8	62.2	64.5	66.8	69.2	71.7	74.1	76.6	79.2
Max	9.9	14.9	20.9	28.0	36.1	40.4	45.0	49.9	55.0	59.2	63.6	68.2	72.9	77.0	81.1	85.4	89.8	94.4	99.1	03.9	08.8	13.8	18.9	24.1
Ratio	0.3	0.3	0.3	0.3	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6

Source: Field Survey, 2007

C. Economics and trade

1. Introduction

The general mode of trade for timber, poles and fuel-wood is basically contractor-based. The local contractors collect wood (timber and poles especially) from the private tree growers and sells them either in the local market i.e. saw mill owners or directly transport to the big city centers like *Kathmandu*, *Pokhara* and *Narayanghat* and *Janakpurdham*. Besides, some farmer-led organization has also taken initiatives for marketing and trade of their forest products. For example, the Terai Private Forest Development Association (TPFDA) in *Dhanusha* district, which is supported by Nepal Agroforestry Foundation (NAF), is engaged in timber and pole marketing to avoid the contractor based marketing channel for the benefits of private tree growers.

2. Methods of market study

This study only covered the local level market of the timber. For this, author had selected only five saw mills out of 20 currently running within the project area. The purpose of saw mill survey was to find out the size of timber in demand in local market and trend of price of timber over time according to its size. The price of each species for each size from 2002 to 2007 has been collected and presented in the table 7.

3. Market value

Teak is used both for timber and plywood. The value of Teak wood is determined by the girth alone. Length is no more important as in s*issoo*. Therefore farmers are not required to have logs of fixed length. The value varies with the girth size (Table 7). Farmers can sell the teak wood either in the saw mills or in the local plywood factory. But farmers are reluctant to sell in the plywood factory because the price set by the plywood owners is much lower than the price of saw mills.

4. Marketable size

The preferred size by the local saw mills runners varies from 2 ft to 6 ft in girth and the price is fixed accordingly. The 6 ft girth is the biggest one, which is rarely produced. The more common sizes are 2, 3 and 4 ft. According to the saw-mill runners, the flow of 3 ft is higher among the three sizes.

5. Market price scenario over time

In the last six years, there has been no change in market price for the size 2ft and 3 ft. The flow of these sizes is higher compared to the other sizes i.e. 4 ft, 5 ft and 6 ft. If we apply the general principle that the value of money decreases over time, investing capital in teak plantation for timber of size 2 ft and 3ft is no more a business of profit. If we see the difference in rate by size class, there is no probability of fetching higher amount by increasing felling period to attain the higher size timber (Table 7). A slight change is there in price in case of size 4ft, 5ft and 6ft in these six years period.

Table 7: Market price of the Teak wood in local sawmills

Dimension						Current Rate/Cft	Year-wise price/c ft							
C (ft)	DBH (ft)	DBH (inch)	DBH (cm)	<, >	L(ft)		2002	2003	2004	2005	2006	2007	Increase in price (%)	Total Price
2	0.6	7.6	19.4			200	200	200	200	200	200	200		
3	1.0	11.5	29.1			300	300	300	300	300	300	300		
4	1.3	15.3	38.8			400	350	350	350	350	400	400	2.7	
5	1.6	19.1	48.5			450	450	450	450	500	500	500	2.1	
6	1.9	22.9	58.3			500	500	500	500	500	600	600	3.7	

Source: Field Survey, 2007
Note:
C : Circumference

6. B/C ratio and rotation period

There are three sizes (I, II and III) basically in demand in the local market (Tables 7 & 9). The first two sizes are attained at the age of 8 and 21 years respectively based on the highest diameter and highest height in the stand. Therefore two rotation periods have been recommended according to the market demand. Due to lack of data, the rotation periods for the size classes III, IV and V can't be determined. If we harvest the crop at 8, we will have two and half rotations in 21 years period (Tables 7, 8, 9& 10).

Table 8: Productivity of a teak stand at different age based on maximum diameter and height

Age	Avg. Dia (cm)	Avg. ht. (m)	H/D	Max. Dia (cm)	Max. Height (m)	H/D	Marketable length(m)		Densit y/ha	Avg. log volume (M^3)		total volume/ha		MAI
							Avg.	Max	(3*2) m^2	Avg.	Max	Avg.	Max	
2	5.04	6.6	1.3	8.70	10.2	1.2	3.36	6.8						
3	5.86	7.7	1.3	10.68	11.0	1.0	3.90	7.3						
4	6.67	7.7	1.1	12.65	11.9	0.9	4.45	7.9			0.10		161.7	40.4
5	7.49	9.4	1.3	14.63	12.8	0.9	4.99	8.5			0.14		233.38	46.7
6	8.30	9.9	1.2	16.60	13.8	0.8	5.53	9.2			0.19		316.73	52.8
7	9.85	10.4	1.1	17.58	14.8	0.8	6.57	9.9			0.23		383.41	54.8
8	11.40	11.0	1.0	18.55	16.0	0.9	7.60	10.7			0.28		466.76	58.3
9	12.95	11.6	0.9	19.53	17.3	0.9	8.63	11.5			0.34		566.78	63.0
10	14.50	12.3	0.8	20.50	18.6	0.9	9.67	12.4			0.4		666.8	66.7
11	16.08	13.0	0.8	21.28	20.1	0.9	10.72	13.4			0.47		783.49	71.2
12	17.65	13.7	0.8	22.05	21.6	1.0	11.77	14.4			0.55		916.85	76.4
13	19.23	14.5	0.8	22.83	23.3	1.0	12.82	15.5			0.59		983.53	75.7
14	20.80	15.3	0.7	23.60	25.1	1.1	13.87	16.7			0.71		1183.6	84.5
15	21.05	16.1	0.8	24.25	26.4	1.1	14.03	17.6			0.79		1316.9	87.8
16	21.30	17.0	0.8	24.90	27.7	1.1	14.20	18.5			0.84		1400.3	87.5
17	21.55	18.0	0.8	25.55	29.1	1.1	14.37	19.4			0.98		1633.7	96.1
18	21.80	19.0	0.9	26.20	30.5	1.2	14.53	20.4			1.04		1733.7	96.3
19	22.20	20.1	0.9	26.86	32.1	1.2	14.80	21.4			1.12		1867	98.3
20	22.60	21.2	0.9	27.51	33.7	1.2	15.07	22.4			1.17		1950.4	97.5
21	23.00	22.4	1.0	28.17	34.0	1.2	15.33	22.7			1.27		2117.1	100.8
22	23.40	23.6	1.0	28.83	34.3	1.2	15.60	22.9			1.39		2317.1	105.3
23	23.80	24.9	1.0	29.49	34.7	1.2	15.87	23.1			1.57		2617.2	113.8
24	24.20	26.3	1.1	30.14	35.0	1.2	16.13	23.4			1.64		2733.9	113.9
25	24.60	27.8	1.1	30.80	35.4	1.1	16.40	23.6			1.77		2950.6	118.0

Source: Field Survey, 2007

Table 9: Income from different size class wood of teak

Size Class	Dimension (in feet)						**Vol. in cu ft**	**Vol. (m^3)**	**Rate/ Cu ft**	**Rate/ m3**	**Total Price**
	Girth (ft)	**DBH (ft)**	**DBH (inch)**	**DBH (cm)**	**<, >**	**Length (ft)**					
Size I	2	0.6	7.6	19.4			1.91	0.05	200	7057.5	**382.00**
Size II	3	1.0	11.5	29.1			4.3	0.12	300	10586.3	**1290.0**
Size III	4	1.3	15.3	38.8			7.64	0.22	400	14115.0	3056.0
Size IV	5	1.6	19.1	48.5			11.9	0.34	450	15879.4	5373.0
Size V	6	1.9	22.9	58.3					500		
	Possible income from the sale of the timber at the age 8 and 21										
Rotation	DBH		vol. Size I	Vol. Size	Vol.	Nos. of	density/		Rate	Total Price (NRs)	

age	(cm)	Vol/tree (m^3)		II	Size III	log	2 *katha*		
8	18.55	0.28	0.1			5	111	382.00	**212010.00**
21	28.17	1.27		0.1		11	111	1290.00	**1515428.00**

Source: Field Survey, 2007

Table 10: Benefit -Cost analysis of the Teak *stand* at the age 8 and 21

				Years																				
Area: 2 *Katha*				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A. Costs																								
Items	**Man days**	**Rate**	**Total**																					
Land preparation	2	100	200	200																				
Pitting	4	100	400	400																				
Seedling cost	150	3.5	525	525																				
Seedling transportation			350	350																				
fencing				5000																				
Weeding	2	100	200	200	200	200	200	200	200															
Pruning										300	300	300	300	500	500	500	500	500	500	500	500	500	500	500
Opportunity cost (Cereal and cash crop)																								
Net income from Millet																								
Net income from Sugarcane				5000	5000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Net income from Vegetables																								
Disease/pest control																								
Final felling cost	40	100	4000								4000													8000
Total cost (year wise)				**11675**	**5200**	**6200**	**6200**	**6200**	**6200**	**6300**	**10300**	**6300**	**6300**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**6500**	**14500**
Present value (PV) with 15% discount rate				**11675.0**	**4521.7**	**4688.1**	**4076.6**	**3545**	**3082**	**2723.7**	**2160.1**	**2059.5**	**1791**	**1606.7**	**1397.1**	**1214.9**	**1056.4**	**918.6**	**798.8**	**695**	**604.0**	**525.2**	**457**	**886.0**
Total PV (8 years)	**36472.5**																							
Total PV (21 years)	**50482.0**																							
B. Benefits																								
Income from intercropping																								
Vegetable				1000	1000																			
Millet/Maize																								
Income from final felling											**212010**													**1515428**
Total benefits				**1000**	**1000.0**						**212010.0**													**1515428**
Present value (PV) with 15% discount rate				**1000**	**869.6**						**79702.4**													**92593.1**
Total PV (8 years)	**81572.0**																							
Total PV (21 years)	**94462.6**																							
NPV (8 years)	**45099.5**																							
NPV (21 years)	**43980.6**																							

B/c ratio (8 years)	**2.2**																							
B/C ratio (21 years)	**1.9**																							

Source: Field Survey, 2007

D. Photo plates

Farmer carrying out pruning in his private teak plantation

Teak nursery

Inflorescence

Pruned Teak tree

Researcher observing a Teak tree for height measurement

15 years old teak Plantation

		
Teak flowers	Teak Unripe fruit	Teak ripe fruit

ANTHOCEPHALUS CHINENSIS

Common bur-flower tree
(Rubiaceae)
Kadam

A. Silviculture

1. Scientific classification

Family:	Rubiaceae
Genus:	*Anthocephalus*
Species:	*A. chinensis*
Scientific Name:	*A. chinensis* Lam.
Local name:	*Kadam*
English Name:	Common bur-flower tree

2. General introduction

Kadam is becoming one of the most frequently planted trees in tropical South Asia. The species is popular because of its fast growth with straight stems and easy tending. *Kadam* is a large pioneer tree up to 45 m tall and up to 1.5 m in diameter. It sheds it leaves in the dry season. Naturally it occurs in secondary forest, sometimes as large trees in primary forest. The species is fast growing when young. It is light-demanding, drought-resistant and has fairly good fire tolerance. It is moderately hard and heavy (specific gravity: 0.40 and calorific value: 4,800), straight grained, somewhat lustrous and medium-coarse in texture.

A. chinensis is a large, deciduous (or sometimes evergreen) species with spreading branches. It can be planted along river and canal banks and the lower part of roadsides. In stiff, badly drained areas growth is very poor, and the species does not thrive in dry areas.

3. Geographic distribution

A. chinensis grows in the sub-Himalayan tract at latitudes from 9 ° S to 27 ° N. The species is native to Australia, China, India, Myanmar (Burma), Sri Lanka Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore and Vietnam and exotic to Costa Rica, Puerto Rico, South Africa, Surinam, Taiwan, Province of China and Venezuela. *A. chinensis* grows in moist, warm regions, often on alluvial ground, along rivers and in swampy areas.

4. Morphology

Stems/crowns

The crown is open and round and bears drooping branches. The stem is straight, more or less cylindrical, and un-buttressed, with a somewhat regular bole. The wood is white to yellowish-white or cream-white with a yellowish cast on a longitudinal surface, often with grayish sap stain of fungi.

Leaves

Leaves are simple, opposite, 12 to 25 cm by 5 to 10 cm, ovate, elliptic-oblong, shining, coriaceous and glabrous above, and pubescent beneath. The tree becomes leafless or nearly leafless during the hot season (figure 1).

Flowers

Flowers are yellow. They are terminal, 3.80 to 5.10 cm in diameter and have a single head, 2.54 to 3.80 cm peduncles, a glabrous corolla, erect lobes, and oblong persistent calyx-lobes.

Bark

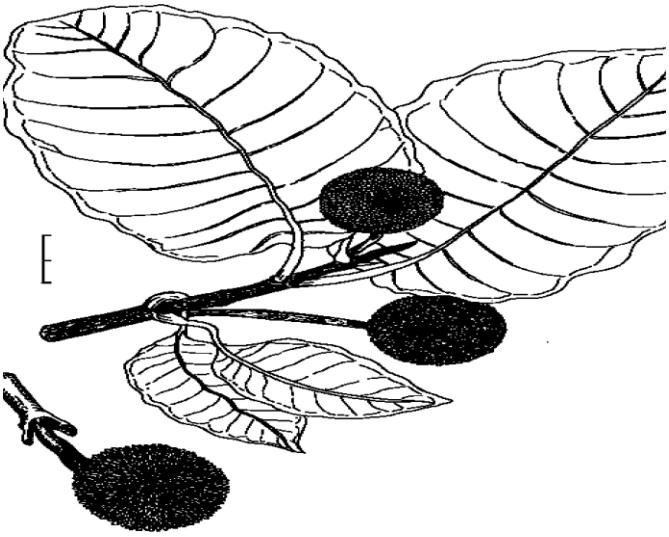
Bark is thin, slightly rough, grayish to light brown and smooth in young trees. It becomes darker and longitudinally fissured in older trees and exfoliates in small rectangular plates that are yellowish brown inside.

Seeds/Fruits

The small fruits of individual flowers are inserted in a central fleshy mass which forms a composite fruit and turns brownish or yellowish when ripe. Fruit is a pseudo-carp which is a *globose*, orange colored fleshy mass of closely packed capsule, each containing a number of minute seeds. The fruit looks like a ping-pong ball. The seeds are angular and not winged (figure 1).

Form

The tree trunk is straight, more or less cylindrical, and un-buttressed with a somewhat regular bole.



(Figure 1: fruits and leaves)

5. Phenology

Blooming season

The scented flowers in globose heads appear from May to June.

Fruiting Season

Fruits ripen in August to October.

Pollination ecology

By air and insects

Seed dispersal ecology

By air and water

Propagation ecology

By seeds alone

Germination Ecology

Germination is epigeous. Seeds germinate in 8 to 22 days. Fresh seeds germinate at 90 percent, diminishing to 5 percent at 13 months. Old seeds germinate best in full sun, and fresh ones in shade.

6. Habitat/ecology

Climate

Kadam is frost sensitive. It grows at elevations of 0 to 1300 m where mean annual rainfall is 1300 to 1400 mm. The tree tolerates a 3-month dry season where the mean maximum temperature is 24 to 34 °C, mean minimum temperature is 16 to 26 °C, and mean annual temperature is 20 to 32 °C. In its natural conditions, the species grows in temperatures from 25 to 35 °C and grows well where annual rainfall is 1440 to 5080 mm.

Soil

The species grows on many soil types, but prefers well drained, fertile soils along streams. *Kadam* tolerates periodical flooding. This broad-leaved species has high fertility requirements and does not grow well on leached soils even when soil physical conditions are good and rooting is not impeded. It grows best on deep, moist, alluvial sites, often in secondary forests along river banks. High to medium texture with neutral to acidic soil is suitable for *A. chinensis*. Free and moist draining conditions are necessary.

7. Patterns of plantation

Pattern

In case of *Kadam*, stand plantation is very common among farmers. Some scattered kind of plantation is also in practice wherever land is available. The *Kadam* plantation is in initial stage in the central *terai*. *Kadam* is one of the highly preferred species for plywood making but there is no record that farmers have sold it to the local plywood factories.

Spacing

In case of the scattered plantation, there is no definite spacing and it is based on the space available while in case of stand, three different spacing systems are in practice i.e. 3*2 m^2 , 3*3 m^2, 5*5 m^2. Spacing varies with objectives of the plantation. When objective is to produce fuel-wood and plywood, narrow spacing is preferred to the wider one. For timber, obviously the preferred spacing would be the wider one.

8. Nursery techniques

Seed collection

Fruits are collected in August and September. They are collected manually from the plant or the ground. Safety belts, ladders, extension pruners, pruning shears, pruning saw, and bags are used in fruit collection. After collection, fruits are left to ripen. Collection of ripe fruits is when they change color to dark brown and before seed is dispersed by wind. The general mode of seed collection is to shake or cut branches with ripe fruits with a long bamboo pole. Fruits should be placed in protected areas, not left under the trees because they may be partially consumed by white ants. The fruits are either dried in the sun so the fleshy part can be removed manually or mechanically, or soaked to separate the seeds. These methods are equally effective. In another method, ripened fruits are soaked in water until they rot, pulped or macerated on newspapers, and dried in a warm place. The seeds are carefully separated from the dried pulp by slightly blowing the mass or by using a fine sieve. Seeds average 18,000,000 to 26,000,000 per kg. Seeds have several years of dormancy and can be stored satisfactorily if they are kept in air-tight or almost air-tight containers in a dark room under dry conditions.

Storage

Dried seed should be stored in airtight containers in a cool and dark place. At room temperature the seed can be stored for at least 6 months when it is dried appropriate. Cool storage of seed can prolong the seed viability up to 2 years.

Seed Biology

No. of seeds per Kg.	Germination percentage	Time for germination (in days)
18,000,000 to 26,000,000	70	8 to 22

Pre-treatment of seed

Pre-treatment to stimulate germination is not necessary.

Seed sowing in nursery beds

Because of the small size of the *Kadam* seed, they are mixed with fine sand in a ratio of 1:10 and sown in seed beds or boxes in February-March. Seeds can also be sown from a salt or pepper pot (Figure 2). After sowing the seed is covered with 1 cm layer of sand to protect the small seed during watering. Germination is epigeous. Fresh seeds germinate at 90 percent, diminishing to 5 percent at 13 months. Old seeds germinate best in full sun, and fresh ones in shade

The seed is broadcasted @ 130 gm per square meter of bed and covered very lightly with fine sailor sand after which watering is done. Excessive watering is to be avoided. Germination starts within 15 days. Seedlings are much subjected to damage by insects. Two-month old seedlings are transplanted into poly pots.

Figure 2: Method of tiny seed sowing by using pepper and salt pot

Soil preparation for the container

The soil mixture for the seed bed or potting mix should consist of 1 part sand and 1 part forest topsoil. About 10-25% of coconut-husks can be added to the mix to improve root growth.

Container size

For *Kadam* polythene bags of sizes 3/5 x 7 inches are appropriate when seedlings stay in the nursery between 8-12 months.

Transplanting

The seedlings are 2.5 cm tall and have 2 or 3 pairs of true leaves after 3 to 4 weeks. After 8-12 weeks the seedlings are dug out of the seedbed and transplanted into containers or poly-bags (Figure 3).

Figure 3: Transplanting *Kadam* seedlings into poly-bags

Watering

A mulch of grass can be used to conserve water and protect seed and soil against large droplets of water. Not too much water should be given in order to prevent damping off. Watering should be done with a fine mist. When seedlings emerge take away the mulch and allow the seedlings to grow in full sunlight.

Weeding

The young seedlings are highly susceptible to weeds and should be weeded regularly. 3-4 weeks old seedlings can be transplanted in nursery beds or into polythene bags (containers), where they can be retained before planting at the start of the monsoon rains.

Fertilizer application

Fertilizer is applied 2 weeks after transplanting to improve seedling growth. This can be repeated every 2 weeks when fast growth is required. Manual weeding needs to be carried out once a month to decrease growth competition for the seedlings.

Root pruning

Root pruning is necessary for seedlings staying in the nursery for a second year. This should be done at least 2 months before planting them out. Only the roots growing out of the polythene bags are to be cut.

Hardening off

Hardening off can be done by increasing the sunlight at the end of April–May by removing the shade net.

Shade and shelter

Around 50-70% of sunlight is required for *Kadam*. No additional protection is needed.

Insects and fungi

Attacks from diseases or attacks from insects are not serious. Sometimes insects attack the leaves recognized by the rolled together leaf. When spotted, they can be removed by hand. Fungi development can be prevented by appropriate watering and ventilation.

Remark

When there are enough seed trees the undergrowth can be removed to stimulate seed germination and natural regeneration.

9. Establishment of plantation

Site preparation

Kadam trees are planted during the monsoon. The planting site is cleared and plowed in March–April and planting holes are prepared before planting in May to July. A firebreak is made with 4–6 m wide strips by plowing, digging or controlled burning. Fencing is required since young saplings are subject to damage from browsing by cattle.

Spacing

The trees are generally planted at (5m x 5m) spacing accommodating 400 trees per hectare, thus leaving ample space for growing other agro-crops. Recommended spacing is 3*3 m^2 for timber production.

Seedling handling

During transport to the planting site the seedlings should be covered by a shade-net to prevent overheating or drying out. Seedlings of 6-7 months of about 0.30 m are suitable to plant out.

Fertilizer application

Artificial fertilizer or decomposed manure should both be used, depending on the soil conditions. In a diameter of 0.30-0.50 m around each seedling 15 gram fertilizer NPK 46-00-00 is applied after 1 month. A second and third application is given after 3 and 5 months and in the second year 1 or 2

applications. In case of planting on slopes, dig 2-3 holes 0.20-0.30 m above the seedling and apply the fertilizer in the holes.

Replacement planting

Replacement planting can be carried out after 1 month.

Weeding

Weeding is carried out 2-3 times per year, with the first weeding after 1 month of planting at the same time as applying fertilizer. Weeding involves clearing all vegetation surrounding the seedling in a diameter of 1 m. This is important as *Kadam* needs full sun light to develop. Weeded material can later be used as mulch around the seedlings. Another two weeding are needed to assist the seedling growth as well as for fire protection. The weeded material can be used as mulch around the seedlings to conserve soil moisture. In Nepal, it's a common practice that farmers carry out weeding four, three, and two times in the first, second, and third years respectively.

Thinning and harvesting

A rotation of 5-7 years is sufficient to produce pulp, and 25-35 years for timber. Thinning should be carried out early and regularly.

10. Diseases and pests

The insect, *Arthroschista hilalaris* attacks *Kadam*. The fungus *Scytalidium lignicola* is found on living branches of A. *chinensis.* The symptoms are typical of a root infection, as the disease occurs in patches and affected trees show cambial and sapwood staining spreading upwards from the roots. Death of feeding roots is another early symptom. The nematodes *Meloidogyne javanica*, *Hemicriconemoides, Tylenchorhynchus* and *Hoplolaimus* are found in association with the roots of A. cadamba. The larvae of 5 common species of *Scarabaeidae*, *Euchlora viridis, Holotrichia constricta, H. helleri, Lepidiota stigma* and *Leucopholis rorida* are polyphagous root pests of *Kadam*.

11. Uses

Kadam wood is light in weight with poor durability. It is used for paper pulp, light interior construction, boxes, ceiling boards, wooden shoes, toys, chop sticks, carving, species is suitable for reforestation of denuded areas and in agroforestry systems as a wind break and shade tree for crops. Leaves and bark have medicinal properties. The leaves can be used as a fodder for cattle. The inflorescences and fruits are edible. From the roots and bark a yellow dye can be obtained.

B. Growth performance

1 Study design and methods

1.1 Study area description

Data presented in the book were collected from the central development region of Nepal, *Dhanusha* district, the project area of Nepal Agroforestry Foundation (NAF), where NAF has been working for 15 years for promoting private forestry in the district. The study covered nine VDCs of the district, where farmers have established stands of *Kadam* of different age ranging from year 4 to 15 years old. The geography of the area is very fragile and soil is sandy and hence the water holding capacity of the area is very low.

1.2 Sample size and sampling intensity

Stands with at least 5 *Kathas* (30 *Kathas* = 1 hectare) of coverage were taken into consideration for the study. Two major variables were measured: DBH and Height. Data were collected from the stands aged 4, 9 and 15. There were altogether 9 stands measured (3 replications). Site quality has been assumed to be the same in each stand. Since the stands are from the same source i.e. NAF's nursery, author assumes that the stand performs the similar growth pattern. The sampling size (unit) was 5*5 m^2 with 2 % sampling intensity. The sampling units were randomly selected. Based on the data from the sample plots, Current Annual Increment (CAI) was calculated and a table was developed which gives the possible DBH and height for each age from 4 to 15.

2. Findings

2.1 Height- diameter ratio

At the initial age, the *Kadam* sapling attains height 1.3 times higher than the diameter. With age the ratio decreases and the rate of height growth gradually slows down as compared to the diameter growth. Diameter growth is a little bit faster at the later age (Table 1).

Table 1: Height-diameter ratio based on the average

	Age											
Parameters	4	5	6	7	8	9	10	11	12	13	14	15
Average Diameter (cm)	5.5	7.5	9.5	11.3	13.2	15.8	17.9	19.6	21.5	22.3	24	25.9
Average Height (m)	7.2	9.7	10.7	11.1	13	14.4	15.7	16.2	17.4	17.2	20	20.6
Marketable length (m)	4.8	6.5	7.1	7.4	8.4	9.6	10.5	10.8	11.6	11.5	13.0	13.7
H/D Ratio	1.3	1.3	1.1	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.8	0.8

Source: Field Survey, 2007

But if we see from the maximum height and maximum diameter ratio, the scenario is different a bit. Until four, when diameter is 1 cm, height will be 1.1 meter. But after four, the diameter growth exceeds the height growth. With age, variation increases indicating that the diameter growth rate is higher than that of height.

Table 2: Height-diameter ratio based on the maximum

Parameters	Age											
	4	5	6	7	8	9	10	11	12	13	14	15
Maximum Diameter (cm)	7.4	11.1	14.8	18.5	22	26	29.75	33.5	34.2	35	36	36.8
Maximum Height (m)	7.8	9.2	11.8	12.8	15.2	17.5	20.3	21.8	22.9	24.5	25.8	26.5
Marketable log length (m)	5.2	6.1	7.9	8.5	10.1	11.7	13.5	14.5	15.3	16.3	17.2	17.7
H/D ratio	1.1	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Source: Field Survey, 2007

2.2 Productivity

The MAI of the stand is slower at the early stage until 9 years. After nine it changes with age abruptly indicating that rapid growth takes place at later ages. Marketable length is determined by height. General assumption is 2/3 of the total height is merchantable (Table 3).

Table 3: Mean annual increment of *Kadam* stand

Age	Avg. Dia. (cm	Avg. Height (m)	H/D	Max. Dia (cm	Max. Height (m)	H/ D	Marketable length (m)		Avg. log volume (m^3)		Total volume/ha		MAI
							Avg.	Max	Avg.	Max	Avg.	Max	
4	5.5	7.2	1.3	7.4	7.8	1.1	4.8	5.2					
5	7.5	9.7	1.3	11.1	9.2	0.8	6.5	6.1					
6	9.5	10.7	1.1	14.8	11.8	0.8	7.1	7.9					
7	11.3	11.1	1.0	18.5	12.8	0.7	7.4	8.5	0.06	0.10	100.0	166.7	23.8
8	13.2	12.6	1.0	22.3	15.2	0.7	8.4	10.1	0.09	0.10	150.0	172.5	24.6
9	15.8	14.4	0.9	26.0	17.5	0.7	9.6	11.7	0.12	0.14	200.0	230.0	25.6
10	17.9	15.7	0.9	29.8	20.3	0.7	10.5	13.5	0.15	0.17	252.1	289.9	29.0
11	19.6	16.2	0.8	33.5	21.8	0.7	10.8	14.5	0.19	0.22	317.6	365.2	33.2
12	21.5	17.4	0.8	34.2	22.9	0.7	11.6	15.3	0.22	0.28	366.7	460.2	38.3
13	22.3	17.2	0.8	35.0	24.5	0.7	11.5	16.3	0.26	0.35	433.4	579.8	44.6
14	24.4	19.5	0.8	36.2	25.8	0.7	13.0	17.2	0.30	0.40	500.1	666.8	47.6
15	25.9	20.6	0.8	36.8	26.5	0.7	13.7	17.7	0.35	0.52	583.5	866.8	57.8

Source: Field Survey, 2007

C. Photo plates

<table>
<tr><td>  </td><td>  </td><td>  </td></tr>
<tr><td>Fruits with leaves</td><td>Fruit</td><td>The pseudocarp with closely packed capsules</td></tr>
<tr><td>  </td><td>  </td><td></td></tr>
<tr><td>Flower</td><td>Kadam tree</td><td></td></tr>
</table>

3 years old plantation

Researcher taking measurement at breast height

References

ASEAN, 2002. *Part II—Species descriptions: Gmelina arborea* Roxb. Page 476-478. Forest Tree Seed Center, Thailand.

Bakshak, M. W. and Basak, A. C., 2000. Mortality of Sisooo in Bangladesh. In proceeding of International Seminar on Die-back of Sissoo, Kathmandu 25-28 April, 2000. FORSPA, FAO, Bangkok, 1-4p.

Ball J.B., Pandey, D., & Hirai, S., 1999. Global overview of Teak plantations. Paper presented to the Regional Seminar "*Site, Technology and Productivity of Teak Plantations*" Chiang Mai, Thailand 26-29 January 1999.

Banarjee, S. K., 1987. Performance of eucalyptus species of various provenances in the lateritic soil of West Bengal. *Van Vigyan* 25 (1-2): 21-35.

DFRS, 2000. Study on die-back of Sissoo. Department of forest research and Survey. Ministry of forest and Soil Conservation, Kathamndu, Nepal. November, 2000.

Duke, J. A., 1983. Handbook of Energy Crops. http://www.hort.purdue.edu/ newcrop/duke_energy/Dalbergia_sissoo.html.

FAO, 2001. Mean annual volume increment of selected industrial forest plantation species. Working paper FP/1. Forestry Department, Rome, Italy.

Francis, J. K., 2002. *Part II—Species descriptions: Tectona grandis L. f.* Page 745-747. Forest Tree Seed Center, Thailand.

Gilman, E. F., & Watson, D.G., 1993. *Dalbergia sissoo* Indian rosewood. Fact sheets ST-277. Forest Service, Department of Agriculture, USDA.

Hawkins, T. 1987. Biomas and volume tables for *Eucalyptus camaldulensis*, *Dalbergia sissoo*, *Acacia auriculiformis* and *Cassia siamea* in the central *Bhabar terai* of Nepal, CFI Occasional paper No. 33.

Hossain, M.K. & Nizam, M.Z.U., 2002. Part II—Species descriptions: *Anthocephalus chinensis* (Lam.) Rich. ex Walp. Forest Tree Seed Center, Thailand. Page: 300-302.

Information from PIER Species list. Plant Threats to Pacific Ecosystems. http://www. hear.org/ pier/ threats.htm

Information from Wikipedia, the free encyclopedia: *Eucalyptus camaldulensis.* http://www. en.wikipedia.org/wiki/Eucalyptus_camaldulensis.

Information from Wikipedia, the free encyclopedia: *Gmelina arborea*. http://www.en.wikipedia.org/wiki/Gmelina_arborea#column-one.

Information on *Kadam*. The wonder agroforestry tree**.** http://www.planning.up.nic.in/innovations/inno3/ fw/kadam.htm.

Jackson, J. K., 1994. Manual of afforestation in Nepal, Second edition. Forestry Research and Survey Center, Kathmandu, Nepal

Kharal, D. K. & Oli, B. N., 2007. An assessment of tree species dynamics in rural farmland of Nepal. *Banko Janakari* 17 (2):3-10.

NAF, 2003. Training manual for nursery management of agroforestry species. Nepal Agroforestry Foundation (NAF), Koteshwor, Kathmandu, Nepal.

Neil, P. 1989. Eucalyptus or other exotics or indigenous species? *Banko Jankari* 2(2): 109-112.

Parajuli, A. V., Bhatia, B., Adhikari, M. K., Tuladhar, J., & Thapa, H. B., 1999. Causal agents responsible for the die-back of *Dalbergia sissoo* in Nepal's eastern terai. *Banko Janakari* 9 (1): 7-14.

Plants of the fabaceae family: *Dalbergia* sissoo. http://www.desert-tropicals.com/Plants/Fabaceae/Dalbergia_sissoo.html.

SANDEE, 2005. Land-use Strategies, Economic Options and Stakeholder Preferences: A Study of Tribal Communities in Forest Peripheries. Working Paper No. 13-05. South Asian Network for Development and Environmental Economics (SANDEE), Kathmandu, Nepal.

Sheikh, A. H., & Md Abdul Matin, 2007. Seed morphology and germination studies of *Dalbergia sissoo* Roxb. at nursery stage in Bangladesh**.** *Research Journal of Agriculture and Biological Sciences* 3(1): 35-39.

Sheikh, M. I. & Haq Raza-ul, 1982. Effect of spacing on the growth of *D. sissoo* (shisham). *The Pakistan Journal of forestry* 32 (2): 73-74.

Thapa, H. B., & Gautam, S. K., 2004. Die-back of *Dalbergia sissoo* plantation in Saptari and Rupendehi districts, Nepal. *Banko Janakari* 14 (2): 19-24.

Thapa, H. B., & Gautam, S. K., 2005. Growth performance of *Tectona grandis* in the western Terai of Nepal. *Banko Janakari* 15 (2): 6-12.

Gautam, S. K., & Thapa, H. B., 2007. Growth performance of *Tectona grandis* Linn F. between two thinning operations at Shankarnagar, Western Terai, Nepal. *Banko Janakari* 17 (2): 11-17.

Thapa, H. B., 1998. Growth of five fast growing tree species in the terai of eastern Nepal. *Banko Janakari* 8(2): 14-22.

USDA. Plants profile for *Dalbergia sissoo*. United States Department of Agriculture. Natural resource Conservation Service, USA. http://www.plants.usda.gov/java/profile?symbol =DASI.

USDA. Plants profile for *Eucalyptus camaldulensis*. United States Department of Agriculture. Natural resource Conservation Service, USA. http://www.plants.usda.gov/ java/profile?symbol=EUCA2.

USDA. Plants profile for *Gmelina arborea*. United States Department of Agriculture. Natural resource Conservation Service, USA. http://www.plants.usda.gov/java/profile? Symbol= GMAR.

USDA. Plants profile for *Tectona grandis*. United States Department of Agriculture. Natural Resource Conservation Service, USA. http://www.plants.usda.gov/java/ profile? Symbol =TEGR.

Varier, P.S., (1997). Indian Medicinal Plants: A compendium of 500 species Vol. V. Pbl. Orient Longman, Hyderabad, India: 245-248.

Winrock International, 1999. *Gmelina arborea:* A popular plantation species in the tropics. Winrock Drive, Morrilton, Arkansas 72110-9370, USA.