
MANUAL OF AFFORESTATION IN NEPAL

Volume 2

by

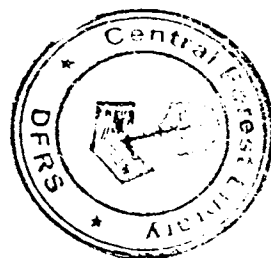
J.K. Jackson

with sections on

Bamboos by C.M.A. Stapleton

and

***Daphne* by J.P. Jeanrenaud**



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Cover photo: Conversion of a plantation block of *Eucalyptus camaldulensis* (Petford provenance) to a seed production area in Sagarnath Plantation, Sarlahi District, Central Development Region. The work has been carried out by the Tree Improvement Programme and the trees are ten years old.

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FOREWORD TO SECOND EDITION

Although the first edition of this manual was published in 1987, it was based on information available to the middle of 1985. Since then there has been a great deal of activity in forestry in Nepal, and much new information has accumulated. There has also been a change in emphasis from larger-scale plantations to tree planting by user groups and individual farmers, though industrial plantations still have a place in the future development of Nepal. For these reasons quite considerable revision of the original manual has been needed.

In this revision much help was received from an informal working group, consisting of Dr S.M. Amatya of the Forest Research and Survey Centre, Ministry of Forests and Soil Conservation; Mr M. Gautam of the Nepal-Australia Community Forestry Project; Dr I. McCracken of the Community Forestry Development Project; Dr T. Parker of USAID working with the Institute of Forestry; and Mr A. Purakka of the United Mission to Nepal.

In addition much co-operation was received from the staff of the Forest Research and Survey Centre and the Nepal-UK Forestry Research Project in Kathmandu. Particular thanks are due to the Librarian, Mr D. Thapa, and his staff, who spent a great deal of time making available a mass of published material.

To all these sincere thanks are due. All errors and omissions, however, are the responsibility of the compiler.

INTRODUCTION

This volume of the manual gives greater details of individual species. More space is given to the most important species, but this is also influenced by the amount of information available. There are some fairly important species about which relatively little has been published. The arrangement for each species follows.

Botanical name

For indigenous species this is in accordance with the *Enumeration of the flowering plants of Nepal* published by the British Museum (Natural History), London (Hara *et al.*, 1978–82). This has involved changes in some names previously used commonly in Nepal, but as the Enumeration can be considered the standard work on the Nepalese flora it is desirable to follow it. Also most of the 'new' names (e.g. *Toona*, *Exbucklandia*) are currently used in foreign, especially Indian, literature. Names of eucalypts follow Jacobs (1979) and of exotic pines the latest available literature.

The botanical name is followed by commonly used synonyms, especially those previously used in Nepal and in older Indian literature. The Enumeration is diverged from slightly in that the families Caesalpiniaceae, Mimosaceae and Papilionaceae are regarded as distinct, rather than being included in the one large family Leguminosae.

Nepali names

These are taken mainly from Howland and Howland (1984) and K. Shrestha (1984) but additions have been made from other sources. No distinction has been made between long and short 'a', nor between the dental and retroflex forms of 't', 'd', 'th' and 'dh'. The form 'ph' has always been used in preference to 'f', and 'bh' to 'v'. The vowel 'u' is always pronounced as in 'rude' rather than as in 'cure'. Orthographic or other minor variants of names are put in brackets.

Nepali names often vary in different parts of the country but it has rarely been possible to indicate in which part of the country a certain name is used, as this information is usually omitted in published lists. It should not be assumed that there is always a one-to-one correspondence between Nepali and scientific names. *Dendrocalamus strictus* is 'bans', but not all 'bans' is this species. In a

few cases well-known English names have been given, e.g. deodar, sissoo and teak, and these have generally been used in the text.

Botanical description

This follows the name, and uses, as far as possible, characteristics easily observed in the field. In many large genera keys to the species have been included, but sometimes unimportant species have not been keyed out.

Occurrence

In this section the terms 'west', 'central' and 'east' Nepal are used in a broad geographical sense, and do not necessarily accord with the Development Regions of the Nepal Government. In the Enumeration the boundary between west and central Nepal is taken at 83°E longitude, and between central and eastern Nepal at 86°30'E longitude. Altitudes are the extremes between which the species occurs; where there is no other information those given in the Enumeration are used. Information is also given on the main forest types in which a species is found.

Silvicultural characteristics

These are given to indicate under what conditions a species may be expected to grow well. They include its tolerance to shade; its resistance to damage by frost, fire and grazing; the types of soil on which it will grow well (though information on this is scarce); and its ability to coppice, pollard or produce root suckers. It should be noted that in Indian literature 'tolerance to drought' often means that the species will tolerate abnormal droughts such as occur at rare intervals in the plains of northern India and may kill quite large trees, rather than merely normal seasonal drought or dry-site conditions. Similarly 'tolerance to frost' may refer to the capability of withstanding abnormal frosts.

Natural regeneration

A brief outline is given on the factors favouring natural regeneration, as far as these are known.

Artificial regeneration

Seed

This includes information on the time of year the seed is available for collection, the number of seeds per kilogram, storage methods and viability under storage, and any pre-treatment the seed needs before it is sown. The time of year that seed ripens is likely to vary in different parts of the country, and also between different years, so this information should be taken as a general guide only. The number of seeds per kilogram of some species is also more variable than the literature suggests. Germination rates are also approximate, since much depends on factors such as the age of the seed and how it has been stored. Rates of germination obtained in the laboratory are rarely achieved under field conditions and for this reason the number of plants produced from 1 kg of seed according to actual nursery records from various parts of Nepal has been given where available. Certainly some of the results could be considerably improved if better techniques were used, but for planning nursery work it is better to base estimates of the amount of seed required on the results obtained in practice, rather than on theoretically ideal figures. For information on seed and nurseries considerable use has been made of Napier and Robbins (1989) *Forest seed and nursery practice in Nepal*.

Nursery techniques

Only those techniques which are particular to the species under consideration are described in detail. These are usually based on raising seedlings in polythene bags, but other techniques such as the use of stumps, cuttings and bare-root plants are mentioned where appropriate.

Plantation techniques

It has rarely been necessary to describe these in detail as basically the same methods are used for all species. It is assumed that the seedlings will be planted as early as possible in the monsoon and in (for the present at any rate) pre-prepared pits. Where different techniques such as winter planting or direct sowing of seed have been successful, or have been tried and have failed, they are mentioned.

Pests and diseases

In general these have been mentioned only when they are so important as to have serious effects on survival and growth, or where special methods have to be adopted to reduce their incidence. Minor rusts and leaf spots occur on a wide range of species, but do relatively little damage; in any case there is little that

can be done in practice to control them. The same is true of a large number of insect defoliators, and borers in the old wood of trees.

Performance in plantations and rates of growth

There is a lack of accurate information on the rates of growth of many species when planted in Nepal, apart from some pines, eucalypts, teak and sissoo, and often growth rates are only available for young trees less than two or three years old. This is unfortunate as many species grow relatively slowly during this period, after which the growth of some accelerates considerably.

In deciding which species to plant rates of growth are very important, as it is obviously better to plant a tree which will reach a diameter of 10 cm (a suitable size for fuelwood) in six years than one which will take twenty years to reach this size—other things, such as the quality of the wood and the survival rate, being equal. For this reason, particularly when information from plantations in Nepal is lacking, the rate of growth of trees in natural forest, especially the mean annual diameter increment, has sometimes been given, mainly from Indian sources. It is appreciated that growth rates in plantations are likely to differ considerably from those in natural forest, and growth rates are also very strongly affected by site quality. However, it is hoped that these figures may be of some value in estimating the relative growth likely to be obtained from different species. In this context a mean annual diameter increment of more than 1.5 cm can be considered fast; between 1.5 and 0.7 cm moderate; 0.7 cm to 0.5 cm slow; and less than 0.5 cm very slow. These figures correspond to an age of 10, 20, 30 and over 30 years respectively needed for the trees to reach 15 cm diameter. This section also includes some information on survival in plantations, though this is greatly influenced by factors such as tending.

Uses

Uses are actual or potential uses in Nepal, and do not include all possible uses recorded from anywhere in the world. Details of timber properties are mostly from Gamble (1922), in particular the weight per cubic metre. This is the most important factor governing the value of the wood for fuelwood, as variation between different species in the calorific value per unit weight is relatively small. Of 24 species listed by Hawkins (1982) 21 had calorific values ± 10 per cent of the mean (20,690 kJ kg⁻¹), and the extreme values were -13.9 per cent and +11.5 per cent of the mean. However, calorific values per kilogram have been given when information is available, though they tend to vary between different published sources.

Considerable attention has been given to the use of leaves as fodder, as this is one of the most important types of forest produce in Nepal. Where the information is available farmers' preferences for different tree species as sources of fodder is given, though this varies considerably from place to place. Often familiar or locally plentiful species are said to be preferred, though others may yield better quality fodder, or higher amounts. Farmers will plant unfamiliar fodder species if they are satisfied that they will produce more or better fodder, as has been shown by the increasing popularity of *Leucaena* until the psyllid arrived, and these need not necessarily be exotic species.

Nutrient analysis of leaves is given when information is available. Among the main sources used are D. Bajracharya *et al.* (1985), Panday (1982) and R.V. Singh (1982). The composition of leaves varies considerably with the conditions of growth of the trees, for example, whether they are growing under wet or dry conditions, and even more with the time of year when the leaves are collected. For these reasons there are often considerable discrepancies between results from different sources, and the figures given should be regarded as useful for comparison rather than exact information on composition.

Where information on yields of fodder from different species has been published this also has been given, though these data must be used with even more caution than the nutrient analysis figures. The information has often been derived from questioning farmers, who no doubt give the best answers they can, but rarely know exactly how much fodder a given tree has produced. Even when yields are based on actual measurements from trees, they are liable to vary immensely. They are influenced not only by the size of the tree, but also the amount of crown competition, intensity of lopping, previous lopping history, and many other factors. S.M. Amatya and Lindley (1992) have shown that even for trees grown under uniform conditions, and lopped at the same time and by the same methods, yield from between 12 and 33 trees would have to be measured to estimate mean fodder yields of different species with an accuracy of as low as ± 25 per cent. In studies in Nepal many trees have rarely, if ever, been measured.

Other uses, including medical uses, have also been mentioned, but only when these are important. Very many trees are used occasionally for medicinal purposes.

Importance in Nepal

This gives a brief indication on the present and potential value of the species in afforestation in Nepal. When a species is used in community forestry, information is also given on farmers' preferences for it.

References

These include the main sources used for each species, other than those mentioned previously in the text, and indicate where further information can be obtained.

***Abies* Juss.**

Pinaceae

Silver Firs

Species of *Abies*, silver fir, form extensive forests over large areas of Nepal at altitudes of between 2100 and 4000 m, and are an important local source of building material. Botanically *Abies* species can be distinguished by having leaves in two ranks which fall off to leave flat circular scars. The cones are cylindrical and erect on the branches; when ripe they break up, and scales and seed fall together.

Key to species

(1) Young twigs without hairs; leaves crowded all round the upper side of the twigs, pointing forwards; apex of leaves with two sharp tapering points; western species *Abies pindrow*

(1) Young stems hairy in the grooves, but soon becoming hairless; leaves distinctly separated on the upper side of the twig, pointing sideways; apex of leaves rounded into a notch 2

(2) Bark soon becoming scaly; twigs brownish; leaves 2.5–5 cm long, and 2.3–3.3 mm wide *Abies densa*

(2) Bark smoother; twigs yellowish; leaves up to 2.5 cm long, and narrower than above *Abies spectabilis*

The second and third species are closely allied, and have often been confused. *Abies densa* is included in Troup (1921) under *A. webbiana* and is called by him the East Himalayan Silver Fir, while *A. webbiana* (*A. spectabilis*) is his West Himalayan High Level Silver Fir. T.B. Shrestha (1984a) doubts whether *A. densa* and *A. spectabilis* are distinct. All species are highly shade-tolerant and prefer cool, moist habitats. They are generally tolerant to frost and snow, though seedlings of *A. pindrow* are sometimes damaged by frost. They are very sensitive to fire, being killed even by light fires. Seedlings can survive under shade, though they grow very slowly. The wood is white in colour, easy to work, but not durable. In Nepal it is used for roofing shingles and other building timber for villages near the forests. Exploitation for shingles is very wasteful, as often several trees are felled before one that is suitable for shingle-making is found. There appears to be no local tradition of sustainable management of fir forests, which are in places being much reduced by overexploitation and fires.

The young twigs and leaves produce an aromatic essential oil, used in preparations for treatment of colds and rheumatism. About 50 t are collected annually, mainly from the west and the Humla-Jumla area.

***Abies pindrow* Royle**

Nepali: chingure, gobre salla.

Occurrence

Abies pindrow has its eastern limit at Dunai, in the Thuli Bheri valley, longitude 83°E, from where it extends westwards as far as Afghanistan. It is found on north- and west-facing slopes from 2100 to 3000 m, usually in damp gullies. Where it occurs, it is usually dominant, but it may be mixed with other conifers such as *Tsuga dumosa*, *Picea smithiana* and *Pinus excelsa*, and broadleaved trees such as *Juglans*, *Aesculus*, *Quercus semecarpifolia* and *Q. floribunda*. It typically occurs at lower altitudes than *A. spectabilis*.

Natural regeneration

In India the seed falls in October and November and normally germinates in May or June; good seed years occur every 3–4 years. If conditions are favourable, such as on newly exposed mineral soil, regeneration is often profuse, but it may fail on impermeable soils, or where there is an accumulation of needle litter. In such cases hoeing the soil is beneficial. Young seedlings benefit from side shade.

Artificial regeneration

Seed

Cones are collected in September and October, not more than a month before they would begin to break up on the trees. Good seed is available once in every three or four years. The cones should be allowed to mature in the shade and break up naturally; they should not be forced open. Seed from unripe cones has low viability. There are about 27,000 seeds kg⁻¹. After collection the wings should be removed by gently rubbing the seeds in a cloth bag, taking care not to damage the seed coats, and then winnowed.

The seed is orthodox, and should be stored in sealed polythene bags after drying for several days in the sun. If it is not dried properly it may be viable for only a few months. If collected from high altitudes the seed may need cold moist stratification. One method of doing this is to place the seed mixed with sand in large clay pots, protected against rodents by wire mosquito gauze. The pots are stood out in the open in a well-drained trench (Hirsbrunner, 1968?). Stratification may also be achieved by sowing the seed in beds as soon as it is

collected, and waiting for it to germinate at the onset of the monsoon. During this period it must be kept moist and protected against rodents. In India 1 kg seed produces 1500 plantable seedlings (Suri and Seth, 1959).

Nursery treatment

As described above the seed can be sown either immediately after collection, if stratification is needed. Otherwise it should be sown at the end of the cold weather, in February or March. Autumn-sown seed will not germinate until the next spring. Germination begins about two weeks after sowing, and is complete within a month.

The normal method is to sow the seed in raised beds at 200 g m⁻². The seedlings should be pricked out into black, or extra thick transparent, polypots shortly after germination, without waiting for the primary needles to appear. Alternatively one or two seeds may be sown directly into the pots. A good potting mixture should be used of three parts soil to one part of sand, plus, if possible, about one part in five of compost. Pricking out should be completed well before the start of the monsoon as firs are susceptible to damping-off and their growth in the nursery is slow. Little growth occurs during the first year after pricking out, and even after two years the seedlings will only be about 10 cm tall. The surface of the soil in the polypots should be cultivated from time to time. At least three years will be needed in the nursery, until the plants are more than 20 cm tall.

For raising bare-root stock the seedlings should be pricked out into raised beds at 15 cm x 15 cm spacing, and either root pruned, or repeatedly transplanted. Suri and Seth (1959) say that two or three such transplantings may be needed.

Plantation methods

For lower altitudes container-raised plants are to be preferred, but at higher altitudes bare-root stock have been successfully used. In India direct sowing has not given good results.

Growth rates

According to Troup (1921) initial growth rates are very slow, but increase after about 10 years to 30–45 cm height growth per annum. In India in natural forest, trees average 6 m in height and 8–13 cm in diameter at 30 years old, and reach 30 m in height by 50 cm in diameter in 110 years; 150 years are needed to reach 60 cm in diameter. Planted trees in India took 20 years to reach a mean height of 2.6 m. A volume table for *A. pindrow* has been prepared by Chaturvedi (1973a).

Importance in Nepal

Where it occurs, at high altitudes in western Nepal, it is an important source of building timber. It has not been planted very much; its very slow rate of growth make plantations rather unattractive.

***Abies spectabilis* (D.Don) Mirb.**

(Syn. *A. webbiana* Lindl.)

Nepali: talis patra, bunge salla, gobre salla.

West Himalayan High Level Silver Fir of Troup.

Occurrence

It is found in central and western Nepal between 2400 and 4400 m. Its eastern limit is unclear, through confusion with *A. densa*; in the west it extends to Chitral, Pakistan. Between 3000 and 3600 m it often forms an almost pure belt. In places it extends to the tree line; elsewhere it is succeeded at higher altitudes by *Betula utilis* forest. It is generally found at higher altitudes than *A. pindrow*.

Natural regeneration

In natural forest less than about 40 years old it is fairly plentiful, but in older undisturbed forest it almost ceases. The young seedlings are very sensitive to fire (Arts and Umans, 1988). Otherwise similar to *A. pindrow*.

Artificial regeneration

There are 8500–12,000 seeds kg⁻¹. Nursery treatment is similar to that for *A. pindrow*, though even longer in the nursery may be needed. It has been planted in the Sagarmatha National Park at high altitudes and also in Solukhumbu on a fairly large scale, where 55 per cent survival has been recorded (J. Stewart, 1984). Direct sowing has also given satisfactory results in the Sagarmatha National Park, and the use of natural seedlings (wildings) collected from the forest and transplanted into containers has been successful in Solukhumbu (J. Stewart, 1984). Because of the slow growth of *Abies* seedlings, weeding two or three times a year for up to five years may be necessary after the trees have been planted in the field.

Rate of growth

At 72 years old, Arts and Umans (1988) estimate a mean diameter of 39 cm, and a biomass of 327 t ha⁻¹, of which 85 per cent is stem timber. This is equivalent to a mean annual increment of about 3.9 t ha⁻¹ of stemwood.

Importance in Nepal

Its value for building timber is similar to that of *A. pindrow*. Though this is of considerable importance locally, remoteness of the forests and extraction difficulties prevent commercial-scale exploitation for timber at present. As a plantation tree, while silviculturally suited to high altitudes, its very slow growth is a drawback.

Abies densa W.Griff. ex Parker.

Nepali: chilro, gobre salla.

East Himalayan Silver Fir of Troup as *A. webbiana* Lindl.

This species is found in eastern Nepal, for instance in the Tamur valley, at altitudes between 3000 and 4000 m. It extends to Assam and Bhutan. Its silviculture is similar to that of *A. spectabilis*. There are 16,000–20,000 seeds kg^{-1} , and 10 kg of cones yield 1 kg of seed. Growth rate in natural forest: 5 m in height and 10 cm diameter in 20 years; annual increment of older forest 3–5 $\text{m}^3 \text{ha}^{-1}$ (Troup, 1921).

References: Arts and Umans (1988); M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhancy and Joshi (1980); Metz (1987); Napier and Robbins (1989); T.B. Shrestha (1984a); Stainton (1972); Suri and Seth (1959); B. Thapa (1989); Trotter (1958); Troup (1921).

Acacia Mill

Mimosaceae

A large genus (about 900 species) of tropical trees, shrubs and climbers. Typically the leaves are bipinnate, with numerous small leaflets, and stipules which often develop into thorns. However in one section, from Australia, adult leaves are replaced by leaf-like phyllodes, which are flattened leaf stalks. The flowers are small, with protruding stamens, and are collected into spherical or cylindrical heads. The fruits are pods. Seven species are included in the *Enumeration of the Flowering Plants of Nepal*, but of these three are climbers and one is an introduced species. Only one species, *Acacia catechu*, is of great economic importance. A very large number of exotic species have been introduced at various times; many have failed and only one so far, *Acacia auriculiformis*, would merit planting on a fairly large scale.

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Indigenous acacias

Acacia arabica see *A. nilotica*.

***Acacia catechu* (L.) Willd.**

Nepali: khayer.

Middle-sized tree; twigs with paired recurved thorns; flowers pale yellow, in cylindrical spikes; pod flattened, brown, shining, 5–7 cm long, containing 6–8 seeds. A useful multipurpose tree for the Terai and lower hills, fairly easy to establish, and of considerable commercial importance as the source of katha and cutch.

Natural occurrence

In Nepal it is widespread in the Terai, and extends to about 900 m (exceptionally to 1400 m). It is very characteristic of the edges of broad river channels in the Terai and dun areas, and often extends some way into the beds of rivers. It also grows freely on the high gravelly terraces of the Seti River near Pokhara, at a considerable elevation above the water level. It is not, however, confined to such sites, and is fairly tolerant of soil conditions. Outside Nepal it occurs throughout most of India and extends to Thailand and southern China.

Silvicultural characteristics

It is a strong light-demander. It grows naturally on a wide range of soils, preferring well-drained, coarse, gravelly alluvial soils, but it also tolerates heavy clay and calcareous soils. On old river terraces near Pokhara it grows well on soils with pH values between 7.4 and 8.9. It is used in India for reafforestation of eroded slopes. It will withstand flooding. The seedlings are somewhat susceptible to severe frosts, but from the sapling stage frost damage is slight. However over most of its range, and the areas where it is likely to be planted, frost is not a major problem. It is very drought-resistant. It needs to be protected against grazing and browsing. *Acacia catechu* is deciduous, shedding its leaves about February, and putting out new leaves at the time of flowering, in June. It coppices well, unless it is in mixture with other species, when these tend to shade out the coppice shoots. The seedling, like that of most acacias, develops a strong taproot.

Natural regeneration

The pods ripen, turning from green through reddish-green to brown, from the end of November to early January. They dehisce soon after ripening, and began

to fall in January though some may remain on the tree until October; by this time, however, most of the seed has been destroyed by insects. The seeds remain attached to the pod valves, which may be blown considerable distances by winds; seed is also disseminated by water. Regeneration is most profuse on exposed alluvial soil in or near river beds. In the open the seedlings will usually be able to develop freely, but under shade most of them will die, due to damping-off and other causes. As stands become older and elevated above the river bed, due to changes in the course of the river, the ground becomes harder and drier and natural regeneration ceases. Apart from unfavourable soil conditions, the main factor limiting natural regeneration is excessive grazing.

Artificial regeneration

Seed

The seed ripens from November to March, according to the locality; January and February are the most usual months for collection. The ripe pods are a dark chestnut-brown and collection should take place as soon as they begin to open on the trees and release the seed. Seed collected in April has given poor germination. It is extracted from the pods by drying them and beating them with sticks. Each pod contains 3–6 seeds. There are 30,000–40,000 seeds kg^{-1} ; an individual tree will yield 0.5–2 kg. The seed should be dried thoroughly and stored in well-sealed polythene bags. As it is very liable to borer attack, a little contact insecticide should be mixed with the seed in the containers. Treated in this way the seed should remain viable for a number of years. Reported short viability, of the order of 6–8 months, may be due to poor storage conditions. As seed is produced in abundance every year long periods of storage should rarely be necessary.

The seed needs pre-treatment before it is sown. Small quantities of seed can be scarified by cutting off a small portion at the end opposite to the hilum. For larger quantities hot water treatment is easier; the seeds are immersed for 2–3 minutes in 15 times their own volume of water which has been boiled and then removed from the heat; they should then be soaked in cold water for 24 hours. Germination of scarified seed begins 3–4 days after sowing, and is complete 6–7 days later. Seed treated with hot water takes 1–3 weeks to germinate. Germination varies from 30 to 80 per cent. Under field conditions in Nepal usually between 5000 and 10,000, occasionally 20,000 plants, have been raised kg^{-1} of seed.

Nursery treatment

The seeds are sown directly into 3 inch x 7 inch (7.5 cm x 18 cm) polypots at the rate of two seeds per pot. A mulch of grass or similar substance is used to cover the soil in the pot immediately after the seed is sown; as soon as most of

the seeds have germinated it is removed. If it is thought that germination rates may be poor, the seed can be pre-germinated. Scarified seed is sown very densely on a well-prepared seed bed or tray, pressed down with a flat piece of wood, covered lightly with sand, pressed down again, and covered with a mulch. As the seeds germinate and produce roots 5–10 mm long, they are removed daily and re-sown into polypots with the rootlet downwards, at such a depth that the seed coat is just covered in soil.

In the Terai the seed should be sown in the first two weeks of April, elsewhere in the last two weeks in March, to produce plantable seedlings 20–30 cm tall by mid-July. In the Terai 12–14 weeks in the nursery is needed, and elsewhere 14–16 weeks. If planting earlier than mid-July is envisaged the sowing dates should be adjusted accordingly. If, shortly after germination is complete, there are two seedlings in a pot one of these should be removed and either pricked out into empty pots or thrown away. Four to five weeks after sowing the pots should be spaced so that there is a 5–10 cm gap between the rows of pots, and at the same time roots should be pruned. This root pruning must be continued every 10–14 days, as acacias develop very vigorous taproots. If root pruning is delayed wilting and dying back of the seedlings is likely to occur. Seedlings which have been kept too long in the nursery should be thrown away, as the strong taproot development will prevent successful planting. No shade is needed, except for two or three days just after seedlings have been pricked out. Stump plants have been used in India, but generally give poorer results than seedlings raised in pots; this method is not recommended. Bare-root plants have given very poor results.

Acacias have a symbiosis with *Rhizobium* bacteria, which form nodules on the roots and fix nitrogen; however artificial inoculation with *Rhizobium* is usually unnecessary, but mixing a little topsoil from *A. catechu* stands into the potting mixture is a useful precaution, if such soil is available near to the nursery.

Planting methods

Planting should not be later than mid-July. For most purposes a planting distance of 2 m x 2 m is suitable. Even in plantations intended to be grown on very short rotations for the production of small fuelwood, closer planting is undesirable, as competition results in plants with very much reduced diameters. At Adabhar in a plantation, 18-month-old trees planted at 1 m x 1 m averaged 1.7 cm in diameter, while those planted at 2 m x 2 m averaged 5.8 cm. The basal area per hectare of the widely spaced trees was nearly three times as much as that of the closely spaced ones. Regular weeding is necessary for at least two years after planting.

Good results have also been obtained by direct sowing of treated seed. Near Pokhara seed was sown in normal planting pits, with the soil filled back in, at the rate of 3–4 seeds per pit. Germination was good and the resulting seedlings vigorous and healthy. If seed is sown in pits, the seedlings should be thinned out to one per pit during the second season after planting. In India the seed is sown in hoed strips 60–90 cm wide and about 4 m apart, often in conjunction with agricultural crops. The crops should not be sown within the hoed strips. Seedlings should be thinned out to one vigorous seedling every metre in the second year, with a further thinning after another 2–3 years, to leave the trees about 2 m apart within the lines.

Susceptibility to injuries

The chief danger to plantations of *A. catechu* is browsing by domestic animals, and if this is likely to be serious effective fencing will be needed.

Performance in plantations and rate of growth

At lower altitudes if plantations are well tended early growth is rapid. At Adabhar 18-month-old trees averaged 4.7 m in height by 5.8 cm in diameter; at Butwal 34-month-old trees were 5.8 m high with a diameter of 6.5 cm. A trial plot 5.5 years old at Tarahara, Sunsari District, at about 200 m altitude in eastern Nepal gave a green weight yield of stem and branchwood of 79 t ha⁻¹, or a mean annual increment of 14.4 t ha⁻¹. This was the highest yield on this site, slightly more than that of *Acacia auriculiformis* and over 40 per cent more than the yield of *Dalbergia sissoo* or *Eucalyptus camaldulensis*. In Uttar Pradesh a crop height of 11.3 m by 12 cm diameter is reached in 10 years, and 16.2 m by 19 cm in 20 years (Indian Timbers, 1973c). For cutch production fairly long rotations are needed, as the proportion of heartwood increases with age. Diameter growth in congested natural stands can be very low; for this reason regular thinnings are essential, particularly in plantations originating from direct sowing. S.P. Singh and Jain (1987) recommend that for the maximum production of cutch there should be 560 trees ha⁻¹ at 10 years; this will produce good yields of cutch on a rotation of 30, 50, or 60 years on good, medium and poor sites respectively. For volume tables see E.R. Sharma and Pukkala (1990b).

Uses

The most important commercial products from *A. catechu* are katha and cutch, obtained by boiling chips of the heartwood. Katha, an impure form of catechin, is mainly used for chewing with betel nut and pan, and also has medicinal and pharmacological uses. Cutch, catechu tannic acid, is used in tanning and dyeing

ships' sails. At one time it was widely used to preserve fishing nets and lines, but the increase in the use of nylon fishing nets is reducing the demand for this purpose. It is also used in oil-drilling operations. *Acacia catechu* heartwood contains 4–6 per cent of catechin and 10–12 per cent cutch (O.P. Sharma, 1984). The wood is hard and heavy, with a specific gravity of about 0.7 air dry, and a calorific value of about 25,600 kJ kg⁻¹. It is excellent for fuelwood and charcoal (Chaturvedi *et al.*, 1986). It is also used for poles in house construction, and for rice pestles, oil crushers, and ploughs. The sapwood is not durable, but the heartwood is very durable. However its value as a source of katha precludes its large-scale use as timber. In India it is reputed to be a good fodder and is lopped to feed goats and sometimes cattle; however it seems to be less popular in Nepal. The leaves contain 12–18 per cent crude protein, and 46 per cent total digestible nutrients.

Importance in Nepal

There are several quite large factories producing katha, mainly for export to India. A typical factory will produce about 400 t yr⁻¹, from about 7000 m³ of timber. Natural forest in India, with scattered *A. catechu*, is estimated to have an annual increment of only 0.06 m³ ha⁻¹ (O.P. Sharma, 1984); thus the production of a single factory would require over 100,000 ha of natural forest if it were to be maintained. The same yield could be produced by 1200 ha of plantation, at a guess, assuming a low mean annual increment of 6 m ha⁻¹. Thus there is a strong case for establishing plantations for the katha and cutch industry, and proprietors of factories should be encouraged to do this. Apart from this, *A. catechu* is a useful multipurpose tree, producing fuelwood, small timber for village use, and fodder. It grows well on gravelly bouldery soils which are not good for agriculture, and could be a useful tree for community plantations in lowland Nepal. However, though in the Chitawan area local people plant it near their houses for timber, it is otherwise not in great demand for planting, as most people in the Terai prefer to plant *Dalbergia sissoo*.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Indian Timbers (1973c); Kulkarni (1956); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Rao and Purkayastha (1972); O.P. Sharma (1984); R.V. Singh (1982); Troup (1921); Trotter (1958).

Acacia nilotica* (L.) Willd. ex Del. subsp. *indica

(Syn. *A. arabica* (Lam.) Willd.)

Nepali: babul, kikar.

A medium to large tree, with dark, fissured bark, and twigs armed with long straight thorns. The yellow flowers are in spherical yellow clusters and the pods are constricted between the seeds. It is doubtful whether this is really native to Nepal; it is found in scattered locations in the lower Terai, from Butwal to Biratnagar, and possibly elsewhere, usually as scattered trees on farms and along roadsides. It is an important tree in the drier parts of India (rainfall less than 1200 mm) where it is used for fodder, fuelwood, timber and tanning. It grows best on alluvial silts near rivers, where it is often flooded deeply each year, but is said to tolerate a wide range of soils including heavy clays. The seedlings are frost-tender. Its ability to coppice appears to vary with the locality where it grows, but is generally poor. It has given very poor results at Adabhar in the Bhabar Terai zone, possibly because the site was too dry for it, but at Shankar Nagar, Rupandehi District (150 m), early survival was very good, though comparative growth was only moderate, considerably below that of *Dalbergia sissoo* on the same site. So far it is not very promising in Nepal. It can be raised either by direct sowing in plantations or from seedlings raised in plastic bags. There are about 9000 seeds kg⁻¹. The seed coat is extremely hard, and in some countries the seed is treated with concentrated sulphuric acid before it is sown. Otherwise the seed must be scarified manually. Hot water treatment is ineffective.

References: The literature on *A. nilotica* is extensive; see the bibliography by Greaves (1984).

***Acacia pennata* (L.) Willd.**

Nepali: arare, arphu.

Usually a climber, occasionally a small tree with scandent branches. Twigs armed with scattered recurved prickles. Flowers white or yellowish in spherical heads. It can be used for stabilizing roadside slopes, being planted as seedlings, or sown directly. It colonizes landslides naturally, but is only found on damp sites and in areas of higher rainfall.

Reference: Howell *et al.* (1991).

Introduced acacias

Acacia auriculiformis A. Cunn. ex Benth.

The most promising Australian acacia so far introduced into Nepal, producing high volumes of fuelwood at lower elevations. It usually has rather a crooked stem. The leaves are replaced by phyllodes; there are no thorns and the flowers are in long spikes.

Natural occurrence

Papua New Guinea, islands of the Torres Straits, Northern Australia and Queensland to 15°S. Mean annual temperature over 25°C ; annual rainfall 1500 to more than 2500 mm, but with up to six dry months.

Silvicultural characteristics

In Nepal well-tended plantations have done well and have produced good yields, at least in their early stages, at altitudes below 500 m. At higher altitudes both survival and growth have been much poorer. It does well on soils of the Bhabar Terai zone, and in very young trials shows promise on highly calcareous usar soils, though time is needed to confirm these results. Elsewhere it is reported to grow reasonably well on poor soils, including shallow soil over laterite, and has been planted on a fairly wide scale in India to reclaim poor sites. For good growth it must be clean weeded for the first 2–3 years after planting. It is not much eaten by cattle and hence is useful where grazing is a problem. Once the canopy has closed it casts a dense shade. It is a strong light-demander, and is reported to be somewhat fire-sensitive. In Adabhar normal coppicing, with stumps about 20 cm high, was not very successful. In Indonesia it has been found to coppice best if cut at least 50 cm above ground.

Nursery and plantation techniques

There are 40,000 to 57,000 seeds kg⁻¹. The seed is normally treated by soaking in hot water at 80°C and leaving to cool for 15–20 hours, but in a trial at Hetauda the percentage germination was 21 per cent for both treated and untreated seed. Germination usually takes 4–5 days, and is over 60 per cent. Seed should be sown directly into containers for planting out the same year; at Hetauda nursery 12 weeks after sowing seedlings were 19 cm tall, and after 16 weeks 23 cm. Thus for trees to be planted in July seed should be sown in March.

Performance in plantations and growth rates

At Adabhar, in the Bhabar Terai zone, it reached a height of nearly 4 m in 1.5 years, and 4.8 m with a root collar diameter of 5.2 cm in 2.6 years. At Butwal,

in the Terai, trees 2.5 years old averaged 6.5 m tall and 4.2 cm in diameter at breast height. At Sagarnath, plantations 2.5 years old produced a mean annual increment of 4.2 t ha⁻¹; at Chitripani 5.5-year-old plantations yielded 7.5 t ha⁻¹ yr⁻¹. At over 1000 m, survival has often been poor, and even when it has been satisfactory growth rates are much slower, e.g. a height of 1.9 m at 3.5 years old at Panchkal (1050 m). So it is of little value at such altitudes. Different provenances vary in their growth rates and if large-scale plantations were to be undertaken more provenance trials would be desirable.

Uses

It is a good fuelwood, with an oven-dry specific gravity of about 0.47 in young trees, and a calorific value of about 25,000 kJ kg⁻¹. It burns slowly with no harmful effects apart from some crackling; it makes good charcoal (Chaturvedi *et al.*, 1986). Its stem tends to be crooked, and so it is not of much value for timber. It is not browsed by cattle, so it is probably a poor fodder species.

Importance in Nepal

It was introduced into Nepal before 1950, when it could be seen near Jhapa on the East-West Highway. It shows considerable promise as a high-yielding fuelwood species in the Terai and Bhabar Terai zones, and could be important for planting on degraded sites.

References: Ghosh (1977); Hawkins (1987a; 1987b); National Academy of Sciences (1979; 1980; 1983b); Sreets (1962); Venkataramany (1963); Webb *et al.* (1984).

Other exotic acacias

Acacia albida Del.

(Syn. *Faidherbia albida* (Del.) A. Chev.)

Leaves bipinnate; twigs with short but stout, straight, white thorns; flowers in spikes; pods curled, yellow. Introduced recently in Dhankuta District; initial survival good. This is a large African tree, growing under rainfall from 500 mm upwards, and at altitudes of up to about 2500 m, but at these heights its growth is stunted. It produces large quantities of pods which are very good fodder; leaf fodder is less important, and its very thorny twigs are likely to be unpopular with Nepali farmers. It has the peculiar property of being deciduous in the rainy season and putting out new leaves after the rains. Hence it does not compete for

light with agricultural crops during their growing season. It is a good nitrogen-fixer.

***Acacia crassicarpa* A. Cunn. ex Benth.**

Similar in appearance to *A. auriculiformis*, but with wider phyllodes. Native of Papua New Guinea and Northern Queensland. At Adabhar, in the Bhabar Terai, early height growth has been good, (height 4.5 m in 17 months) but survival rather poor. At higher altitudes growth rates are poor (1 m in 3.5 years). Its rapid height growth at lower altitudes would justify further trials as a high-yielding fuelwood species, but until such trials have been made larger-scale plantations are not recommended.

Reference: (Neil, 1990a).

***Acacia dealbata* Link**

Silver wattle.

Leaves bipinnate; no thorns; leaflets less than 5 mm long; branches and leaves hoary with very short hairs; flowers deep yellow. A native of eastern Australia, from Tasmania to Queensland, which is reported to be more cold-resistant than black wattle, *A. mearnsii*. However results of trials in Nepal have not been very promising, the best being at Syaule (2050 m) with 89 per cent survival and a mean height of 1.0 m at 1.5 years old. There was little difference between the two varieties, var. *dealbata* and var. *subalpina*. At high altitudes it performs slightly better than other wattles, but in the harsh conditions of the mountains of Nepal large-scale planting is unlikely to be important.

***Acacia decurrens* (Wendl.) Willd.**

Green wattle.

Leaves bipinnate; no thorns; leaflets 5–12 mm long; twigs almost hairless; flowers pale yellow. There have been a number of trials in Nepal, between 1000 and 2200 m, many of which have failed; in others survival and growth have been rather poor. However at Tistung (2000 m) one of the few survivors of an early trial reached 10 m in height by 14 cm dbh at 5.5 years old, and in a later trial, 3.5 years old, survival was 63 per cent and mean height 1.5 m. There may possibly be some future for the species.

Reference: (Neil, 1990a).

Acacia decurrens (Wendl.) Willd. var. *mollis* Lindl. see *A. mearnsii*.

***Acacia farnesiana* (L.) Willd.**

Superficially resembles *A. nilotica*; best distinguished by the pods, which are cylindrical and not constricted between the seeds. Native of Central America, now naturalized in India and parts of Nepal up to 1100 m, where it is found as scattered trees, usually in towns or villages. It grows to about 5 m tall. In India the leaves and pods are used for fodder. A perfume (cassie flower) is extracted from its flowers, especially in southern France. It makes a good hedge. It might be of interest for people to plant near their houses. About 11,000 seed kg⁻¹.

Acacia flavescens

Native of Queensland. Included by the Nepal–Australia Forestry Project, in trials in the Kathmandu Valley. At Trisuli survival was 80 per cent, and mean diameter 3.6 cm, after six years (M.R. Joshi and Wyatt-Smith, 1982). Trials elsewhere have given poor results. Not promising.

***Acacia mangium* Willd**

Leaves replaced by phyllodes, broader than those of *A. auriculiformis*. Native to the Moluccas, Irian Jaya, Papua New Guinea and small areas of Queensland. It is essentially a species of the constantly humid tropics, where it produces very high yields, but is less well adapted to areas with a marked dry season. Trials of this species and its hybrid with *A. auriculiformis* have given poor results in Nepal, and it is clearly unsuited to the area.

Reference: National Academy of Sciences (1983a).

***Acacia mearnsii* De Wild.**

(Syn. *Acacia mollissima* auct. non Willd.; *Acacia decurrens* Willd. var. *mollis* Lindl.)

Black wattle.

Leaves bipinnate; no thorns; leaflets 1.5–4 mm long; young shoots with golden yellow hairs; flowers pale yellow, in spherical heads. This tree is native to Australia, from Tasmania to southern Queensland, along the coast and coastal mountains. It has been very widely planted elsewhere, particularly in eastern and southern Africa, as a source of tanbark. Seedlings are frost-tender, and in general results of trials in Nepal have been poor. One exception was at Butwal

in the Terai where at the age of 30 months there were 94 per cent survival with a mean height of 5.6 m. Even here growth rates were inferior to those of many other species, including *Eucalyptus camaldulensis*, *Dalbergia sissoo* and *Acacia auriculiformis*. Elsewhere a few isolated trees have survived in various places, and occasionally these have grown rapidly; M.R. Joshi and Wyatt-Smith (1982) record trees 10–12 m in height by 25 cm in diameter, aged 8 years, at Kirtipur, and 10 m in height by 16 cm in diameter, aged 4 years, at Godavari. However it seems to have little future as a plantation tree. There are 60,000–100,000 seeds kg⁻¹ and the seed can be stored without difficulty for many years. Before it is sown it needs to be treated with hot water.

***Acacia melanoxylon* Sm.**

Trade name: Australian blackwood.

Leaves replaced by phyllodes, which have 3–5 veins; no thorns; flowers in globose heads. It has been tried at a number of sites at different altitudes in Nepal; survival has in general been poor, and height growth only moderate. Thus though it has been successful in mountainous regions elsewhere in the tropics, conditions in Nepal appear to be too harsh for it. About 70,000 seeds kg⁻¹. Hot water treatment necessary.

Miscellaneous acacias

Since 1986 a large number of species have been tried, many of them from seed provided by the Tree Seed Centre of Australia. Results from these trials, and a few other introductions, are summarized below. A = age in months (mon.); S = survivors; H = mean height.

Acacia adunca

Thulo Sirubari (1400 m): A=31 mon.; S=50%; H=1.2 m.

Acacia ampliceps

Adabhar (250 m): A=19 mon.; S=2%; H=2.2 m; failed. Results at Nepalganj (200 m) from a trial less than one year old, on a soil with high calcium content were fairly promising (K.J. White, 1988b). Too early to draw conclusions.

Acacia aneura

Adabhar (250 m): 1982; poor.

***Acacia aulacocarpa* Benth.**

Panchkhal (1050 m): A=28 mon.; S=47%; H=0.9 m. Thulo Sirubari (1400 m): A=28 mon.; S=25%; H=0.8 m; poor survival and growth.

***Acacia baileyana* F. Muell.**

Pharping (1770 m): 1973; all died.

Acacia brassii

Panchkhal (1050 m): A=28 mon.; S=72%; H=1.4 m. Thulo Sirubari (1400 m): A=28 mon.; S=46%; H=1.1 m.

Acacia citrinoviridis

Panchkhal (1050 m): A=28 mon.; S=19%; H=0.8 m. Thulo Sirubari (1400 m): All died; failed.

Acacia conferta

Thulo Sirubari (1400 m): A=31 mon.; S=5%; H=0.3 m; failed. Sindhupalchok (1430 m): Also failed.

Acacia cunninghamiana

Thulo Sirubari (1400 m): A=31 mon.; S=5%; H=0.4 m. Panchkhal (1050 m): Poor results, also failed.

Acacia deanii

Thulo Sirubari (1400 m): A=31 mon.; S=72%; H=0.8 m; survival fair, height growth poor.

Acacia difficilis

Panchkhal (1050 m): A=28 mon.; S=59%; H=2.5 m. Thulo Sirubari (1400 m): A=28 mon.; S=54%; H=1.8 m; survival rather poor, height growth good.

Acacia falcata

Kadambas (1600 m): A=18 mon.; S=5%; H=0.3 m.

Acacia falciformis

Thulo Sirubari (1400 m): A=31 mon.; S=20%; H=0.7 m. Kadambas (1600 m): A=18 mon.; S=2%; H=0.3 m. Syaule (2050 m): A=18 mon.; S=53%; H=0.5 m.

Acacia filicifolia

Kadambas (1600 m): A=18 mon.; all dead. Syaule (2050 m): A=17 mon.; S=73%; H=1.2 m. Deorali (2400 m): A=14 mon.; S=28%; H=0.1 m; damage by hares.

***Acacia fimbriata* G.Don**

Thulo Sirubari (1400 m): A=31 mon.; S=50%; H=1.0 m.

Acacia floribunda

Thulo Sirubari (1400 m): A=31 mon.; S=47%; H=0.7 m

Acacia glaucocarpa

Kabhre (1050 m): Failed, though rather poor trial.

Acacia holosericea

Adabhar (250 m): provenance Vaughan Springs, N.T.—A=24 mon.; S=44%; H=2.4 m; provenance Mt Molloy, Q.—A=24 mon.; S=68%; H=2.8 m. Gorlikharka (600 m): A=12 mon.; S=93%. Panchkhal (1050 m): A=40 mon.; S=23%; H=2.0 m. Panchkhal (1050 m): A=28 mon.; S=75%; H=1.1 m; second trial. Thulo Sirubari (1400 m): A=28 mon.; S=79%; H=1.0 m. Thulo Sirubari (1400 m): A=16 mon.; S=85%; H=1.1 m; second trial. Kadambas (1600 m): A=7 mon.; S=100%; H=0.2 m. At Nepalganj on limy soil, at seven months old it was growing vigorously, with a single stem, and was best in the trial. This species, although inferior in growth to *A. auriculiformis*, merits further trials.

Acacia homalophylla

(correct name *A. omalophylla* Benth.)

Thulo Sirubari (1400 m): No survivors.

Acacia implexa

Kadambas (1600 m): A=18 mon.; S=7%; H=0.2 m; failed.

Acacia irrorata

Panchkhal (1050 m): A=28 mon.; S=9%; H=0.6 m. Thulo Sirubari (1400 m): A=28 mon.; S=83%; H=0.5 m.

***Acacia koa* Gray**

Native of Hawaii; introduced before 1985 but failed in all trials.

Acacia leptocarpa

Adabhar (250 m): A=17 mon.; S=24%; H=3.1 m. Panchkhal (1050 m): A= 40 mon.; S=47%; H=1.5 m. Thulo Sirubari (1400 m): A=28 mon.; S=34%; H= 0.7 m. Survival at lower altitudes rather poor, but height growth fairly good; further trials might be justified.

Acacia leucoclada

Kadambas (1600 m): A=29 mon.; S=53%; H=0.9 m; other trials at Kadambas had much lower survival.

Acacia maconochieana

Panchkhal (1050 m): A=28 mon.; S=9%; H=0.7 m. Thulo Sirubari (1400 m): All died; failed.

***Acacia neriifolia* Benth.**

Panchkhal (1050 m): A=30 mon.; S=16%; H=1.5 m. Thulo Sirubari (1400 m): A=28 mon.; S=8%; H=0.6 m. Kadambas (1600 m): A=18 mon.; S=2%, H= 0.6 m. No survivors at Adabhar and Panchkhal; failed.

Acacia paramattensis

Thulo Sirubari (1400 m): A=31 mon.; S=22%; H=1.1 m.

Acacia pellita

Panchkhal (1050 m): A=28 mon.; S=87%; H=1.4 m. Thulo Sirubari (1400 m): A=28 mon.; S=25%; H=0.5 m. At about 1000 m survival good, and comparatively good height growth; poor at higher altitudes.

***Acacia pendula* A. Cunn. ex G. Don.**

Planted at Adabhar (250 m) in 1982, but results poor.

Acacia perangustata

Kabhre (1050 m): Failed, though rather poor trial.

Acacia plectocarpa

Adabhar (250 m): A=18 mon.; S=28%; H=2.6 m.

***Acacia podalyriifolia* G. Don**

Adabhar (250 m): A=19 mon.; S=10%; H=2.8 m. Gorlikhaka (600 m): A=12 mon.; S=48%; dieback. Thulo Sirubari (1400 m): A=17 mon.; S=80%; H=1.1 m; prov. 1149—A=16 mon.; S=40%; H=0.7 m; prov. 1075—A=16 mon.; S=65%; H=1.3 m; best this trial. Kadambas (1600 m): A=18 mon.; S=10%; H=0.6 m. Shows some promise at altitudes round about 1400 m.

Acacia polybotrya

Kabhre (1050 m): Failed, though rather poor trial.

***Acacia salicina* Lindl.**

Adabhar (250 m): A=19 mon.; S=2%; H=1.6 m; failed.

***Acacia saligna* (Labill.) H. Wendl.**

Thulo Sirubari (1400 m): No survivors.

***Acacia shirleyi* Maiden**

Panchkhal (1050 m): A=28 mon.; S=41%; H=0.4 m; failed.

Acacia silvestris

Thulo Sirubari (1400 m): A=31 mon.; S=20%; H=0.3 m. Syaule (2050 m): A=17 mon.; S=37%; H=0.5 m. Deorali (2400 m): A=14 mon.; S=10%; H=0.1 m; hare damage.

Acacia simsii

Adabhar (250 m): A=24 mon.; S=12%; H=1.8 m. Panchkhal (1050 m): A=40 mon.; S=70%; H=1.8 m. Thulo Sirubari (1400 m): A=28 mon.; S=25%; H=1.3 m.; A=16 mon.; S=75%, H=0.9 m; second trial.

***Acacia spectabilis* Benth.**

Thulo Sirubari (1400 m): A=31 mon.; S=17%; H=1.3 m.

***Acacia stenophylla* Benth.**

Adabhar (250 m); Panchkhal (1050 m); Thulo Sirubari (1400 m): No survivors.

Acacia torulosa

Adabhar (250 m): A=19 mon.; S=28%; H=3.2 m. Panchkhal (1050 m): A= 40 mon.; S=37%; H=2.3 m. Thulo Sirubari (1400 m): A=16 mon.; S=60%; H= 0.4 m.

Acacia trachyphloia

Thulo Sirubari (1400 m): A=31 mon.; S=17%; H=0.4 m.

Acacia tumida

Adabhar (250 m): A=24 mon.; S=44%; H=2.8 m. Panchkhal, (1050 m): A= 40 mon.; S=53%; H=1.9 m. Thulo Sirubari (1400 m): A=16 mon.; S 60%; H=0.5 m.

***Acacia victoriae* Benth.**

Tried at Adabhar before 1985, but with poor results; failed at Kadambas (1600 m).

Of these new introductions only *A. holosericea* and *A. podalyriifolia* would merit further trial, based on their survival rate and growth. Neither is a very good fodder, and it is doubtful whether they would be better sources of fuel-wood than species already grown in Nepal.

***Acer* L.**

Aceraceae

Maples

Trees with opposite leaves, which are usually palmately lobed, occasionally entire; flowers in elongated or flattened clusters; fruits of two carpels, joined together, each with a long membranous wing. Thirteen species are indigenous, all of which are medium to large trees, but none is planted on a large scale in Nepal. Most are used as fodder, but not on a very large scale. Three species planted in Nepal or India are dealt with below.

***Acer caesium* Wall. ex Brandis**

Fairly large deciduous tree. Leaves pale beneath, with five lobes, lower pair much smaller than the rest, edges saw-toothed. Flowers greenish-yellow, in flat-topped clusters.

Natural occurrence

Found in Nepal between 2200 and 3000 m; extends as far west as Kashmir. In western Nepal it is commonly associated with *Quercus floribunda*, and in moist forest near streams with *Aesculus* and *Juglans*. It is less common in central Nepal and is absent in the east.

Silvicultural characteristics

A moderate light-demander, and frost-hardy; not readily browsed by cattle. Its growth is slow, natural seedlings taking four years to reach 60 cm in height. It coppices well. The seedlings have a strong taproot. The trees shed their leaves in November, and put new ones out between March and May.

Natural regeneration

The seed lies on the ground during the winter and germinates next spring. It is particularly abundant on newly exposed, porous soil, and colonizes landslips. It fails to establish itself where there is heavy weed growth.

Artificial regeneration

The two-winged fruits ripen in July to October; they are threshed, dried in the sun, and stored in sealed containers until needed for planting. There are about 12,000 seeds kg⁻¹. Germination of fresh seed is good, but rather slow, taking up to six weeks. Seed should be sown in the nursery in March, either directly into

containers, or in beds for later pricking out into containers. They will need at least 15 months in the nursery, possibly one year more.

Uses

The wood weighs about 640 kg m^{-3} , and is white, close grained, soft to moderately hard. It is not durable. It is used for making bowls, and is suitable for turnery and similar purposes. The leaves are used for fodder in Jumla (Raeside, 1985), but as the tree is deciduous, are not available for most of the winter.

Importance in Nepal

It has been raised in community forestry nurseries in Nepal, but only on a small scale. It is used as a plantation species in Himachal Pradesh, India.

References: Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); Lamichhancy and Joshi (1980); Suri and Seth (1959); Troup (1921).

Acer campbellii Hook. f. and Thom. ex Hiern

Nepali: yarla, yali, kapasi.

Small to medium tree; leaves five-lobed, the lobes ending in long tail-like tips; margins finely toothed; flowers cream to reddish, in elongated clusters.

Natural occurrence

Found in Nepal between 2100 and 3600 m; extends eastwards to Burma. A characteristic component of the upper temperate mixed broadleaved forest.

Silvicultural characteristics

It is deciduous and a moderate light-demander; seedlings do not tolerate dense shade. Best reproduction is on disturbed soil. It coppices well.

Artificial regeneration

The fruits ripen in November–December; they are threshed, dried in the sun, and stored in sealed containers. There are about 23,000 seeds kg^{-1} , and 1 kg of fruit will produce about 280 g of clean seed. Germination percentage is good, up to 75. Seed should be sown directly into containers, or in beds for later pricking out, in March to April. The sowing rate in beds should be about 60 seeds m^{-2} . The seedlings should be pricked out when 5–8 cm high. They will need to be kept in the nursery for a further year after pricking out, when they should have reached a height of about 30 cm.

Performance in plantations and rate of growth

In the Darjeeling, India, in plantations at 2000 m, after five years average height was 2.4 m. In 36 years trees reached a height of 15.5 m and a diameter of 19 cm.

Uses

The wood weighs 600–640 kg m⁻³. It is widely used in the Darjeeling area of India for planking and tea chests; it can also be used for turnery. The leaves are used to some extent as fodder in the Indian east Himalaya.

Importance in Nepal

It has been little planted in Nepal, but is an important species in the eastern Himalaya of India.

References: Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); Lamichhaney and Joshi (1980); Suri and Seth (1959).

***Acer oblongum* Wall. ex DC.**

Nepali: phirphire, putali phul.

Small to medium-sized evergreen tree. Leaves lance-shaped, not lobed or toothed. Flowers greenish-white in dense branched clusters.

Natural occurrence

It grows at lower altitudes than do other species of *Acer*, between 1200 and 2400 m. In places it is associated with *Schima*. It is common in the Kathmandu Valley and can be seen on Swayambunath Hill. Outside Nepal it extends from Kashmir to Thailand and southern China.

Silvicultural characteristics

Probably somewhat less frost-tolerant than the species described above, though provenance could be important in this respect. It needs good drainage and a porous soil for satisfactory growth. It coppices well.

Natural regeneration

It needs shade in its early stages, and good regeneration is found under the shade of broadleaved forest.

Artificial regeneration

According to Indian sources the fruit ripens during the cold season, from December to April; it hangs on the trees for some time. M.W. Campbell

(1983a) reports it as falling between June and August, but it has also been recorded as ripening in March (Department of Medicinal Plants, 1973). There are about 10,000 fruits or 21,000 cleaned seeds kg^{-1} , but the seed weight varies with the locality. The viability of the seed is reputed to be relatively short, and it should be sown soon after collection, either in beds or directly into containers. It will normally require about 15 months in the nursery.

Performance in plantations and rate of growth

In India plants four years old ranged in height from 0.6 to 3.2 m. Naturally grown trees have an annual diameter increment of about 0.7 cm. The Nepal–Australia Forestry Project included it in their trials at Godavari, Lower Nagarkot and Upper Nagarkot. At these sites survival was fairly good, height growth slow. At Godavari (1500 m) at six years old only 35 per cent of the survivors were over 2 m in height; elsewhere growth was poorer.

Uses

It produces a light brown, close-grained timber, weighing about 720 kg m^{-3} . Its uses are similar to those of other species of *Acer*. It is said to produce a medium-quality fodder in India.

Importance in Nepal

It has been raised on a small scale in community forestry nurseries, but is not in great demand. Small areas have been planted. It is used for fodder where it occurs. In Lalitpur District, south of Kathmandu, it is lopped in April, but it is not one of the most important fodder trees (Upton, 1990).

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); M.R. Joshi and Wyatt-Smith (1982); Lamichhane and Joshi (1980); Troup (1921).

***Acrocarpus* Wight and Arn.**

Caesalpiniaceae

***Acrocarpus fraxinifolius* Wight and Arn.**

A very large tree. Leaves bipinnate; leaflets 5–12 cm long, pointed. Flowers dull red or orange, in erect racemes. Pods thin, flat, with a narrow wing on one side. Although native to eastern Nepal, it was not tried in plantations until the early 1980s. At lower altitudes early growth has been very rapid, and if this is

maintained it will be a valuable fast-growing source of fuelwood and timber at altitudes below 500 m. It is unsuccessful at higher altitudes.

Natural occurrence

In Nepal it is confined to the east, where it is a constituent of the tropical evergreen forest, between the Koshi and the Mechi rivers, often growing near streams. It is widely distributed in the tropics, from peninsular India to the eastern Himalayas, Burma and Sumatra, usually in areas with more than 1800 mm rainfall; it reaches 1300 m altitude in Sikkim.

Silvicultural characteristics

It is a deciduous tree, light-demanding, and somewhat frost-sensitive; it needs good drainage. Its natural habitat is the humid tropics with a well-distributed annual rainfall, and it has also done well on deep soils in cool frost-free tropical uplands. It grows rapidly on good sites, but tends to be disappointing on some poorer sites, where rapid growth for a few years may be followed by stagnation. It does not form root nodules with *Rhizobium* species, and hence does not fix nitrogen.

Natural regeneration

The fruit ripens just before the onset of the monsoon. The seed may germinate almost immediately, but it may also lie dormant for up to a year. In India regeneration is reported to be plentiful. Seedlings can withstand some shade, but later full light is preferred.

Artificial regeneration

Seed

The seed is collected from late April to mid-May, when the pods have turned brown but before they open. The pods are dried in the sun and beaten with sticks to extract the seed. There are about 32,000 to 46,000 seeds kg⁻¹. The seed is orthodox and should be dried and stored in sealed polythene bags, when it will remain viable for many years. However it is very liable to borer attack while in storage. This can be reduced by removing damaged seeds, and any insects, before storage, but mixing a little contact insecticide with the seed is safer. The seed has a hard coat, and if untreated will germinate sporadically over many months, with a germination of less than 10 per cent. The most certain treatment is by hand scarification with a sharp instrument; if this is done germination will begin in 3–4 days and will be complete 10 to 14 days later. Treatment with hot water has been found to be less effective, giving less than 30 per cent germination.

Nursery treatment

Plants raised in polythene bags are the type of nursery stock most commonly used. Two treated seeds are sown into each bag, and after sowing, mulch is applied to the surface soil. Surplus seedlings may be pricked out into empty bags. Four or five weeks after the seed is sown the plants should be spaced at 5 to 10 cm between the rows, and the roots pruned. Regular root pruning should continue every 10–14 days. In the Terai 12–14 weeks will be needed in the nursery; elsewhere 14–16 weeks. In India it is reported that stumps have been used successfully.

Plantations

For good growth, complete cultivation, or intercropping with an agricultural crop, is necessary for the first two or three years after planting; after this *Acrocarpus* controls grass effectively. Very close planting with the aim of producing small fuelwood on a very short rotation is not very promising, as competition soon sets in between the trees. At 1 m x 1 m spacing at Adabhar the volume per unit area at 32 months old was only 60 per cent of that from spacing at 2 m x 2 m, despite there being four times as many trees per hectare. It has done well in mixtures with *Eucalyptus camaldulensis*, *Leucaena leucocephala* and *Indigofera teysmannii* (see page xx). In India direct sowing is said to have been successful.

Performance in plantations and growth rates

At low altitudes early growth has been very rapid. Some of the data are included in Table 20 (page 362). At the age of 18 months the total green weight biomass from a plantation at Adabhar at 1.5 m x 1.5 spacing was estimated at 40 t ha⁻¹, equivalent to a mean annual increment of 27 t ha⁻¹. At Tamagadhi, at 26 months, in a mixed plantation with *Indigofera teysmannii* the total above ground oven-dry wood biomass of the *Acrocarpus* was 10.2 t (MAI 4.7 t ha⁻¹). These growth rates are among the highest for species tried at these sites, except for the better provenances of *Eucalyptus camaldulensis*. At higher altitudes growth is much poorer. For instance at Chirtungdhara, Palpa District (800 m), aged 31 months, there were 77 per cent survivors with a mean height of only 60 cm. In trials at altitudes over 1400 m it has failed completely.

Table 20—Performance of *Acrocarpus fraxinifolius* in plantation

Site	Age (months)	Survivors (%)	Mean height (m)	dbh (cm)	Remarks
Adabhar (250 m)	18	97	5.3	5.6	
	32	72	6.9	5.2	
	32	—	6.7	9.3	2 m x 2 m
	32	—	5.3	3.4	1 m x 1 m
	31	87	9.4	7.7	Mixed <i>Eucalyptus camaldulensis</i>
Butwal (140 m)	18	75	7.0	6.9	
	18	—	6.1	6.5	Pure
	18	—	6.5	7.7	Mixed <i>Leucaena leucocephala</i>
	18	—	6.4	7.7	Mixed <i>Cassia siamea</i>
	30	83	8.2	6.1	

Uses

It produces a fairly hard, strong timber used for furniture, boards, general construction and roofing timbers. It weighs about 600 kg m^{-3} . It is not durable. As fuelwood it has a calorific value of about $27,700 \text{ kJ kg}^{-1}$, which is high. It burns slowly, but with continuous light cracking, and produces a somewhat acrid smoke.

Importance in Nepal

If early growth is maintained it will be one of the most important species for high volume production in the Terai and Bhabar Terai. Even if it stagnated after about five years it would still give high fuelwood yields, though the quality of the fuelwood for domestic use appears not to be very high.

References: Chaturvedi *et al.* (1986); Gamble (1922); Gildyal (1989); Ghosh (1977); Napier and Robbins (1989); National Academy of Sciences (1979); Neil (1990e); Rao and Purkayastha (1972); R. Shaky (1990); Streets (1962); Troup (1921); Webb *et al.* (1984).

Adhatoda vasica see *Justicia adhatoda*.

***Adina* Salisb.**

Rubiaceae

***Adina cordifolia* (Willd. ex Roxb.) Benth. and Hook.f. ex Brandis**

Nepali: haldu, karma, kiram.

Trade name: haldu.

A large deciduous tree, up to 40 m tall by 2.2 m in diameter. Leaves opposite, heart shaped, 10–22 cm long. Flowers yellow, in round heads up to 2.5 cm in diameter, on long stalks. Fruits very numerous, in round heads. An important timber tree in the Terai, so far only planted on a small scale.

Natural occurrence

In Nepal it is common in *Shorea robusta* forest, both in the plains and the hills, up to about 800 m. Outside Nepal it is found throughout most of India, and extends to Indochina in the east.

Silvicultural characteristics

A light-demanding tree, growing best on freely drained soil, for instance on lower slopes of hills among boulders. It grows on a wide range of soils, and will tolerate soils with high pH values, up to 8.3. It is susceptible to frost damage and to fires. It coppices readily.

Natural regeneration

The seed is shed between April and June, and is often carried fairly long distances by the wind. It germinates early in the rains, and to establish itself successfully the seed must fall on bare ground, such as landslips, alluvial soil near rivers, and abandoned cultivation. The young seedlings are very small and liable to be washed away or beaten down by rain. Growth in the first year is very slow, and the seedlings often reach only 2.5 cm in height during this time; in the second year growth is faster, and the seedlings develop thick taproots. The young seedlings appear to benefit from shade, but if this continues growth remains stunted until the canopy is opened to admit more light.

Artificial regeneration

Seed

The seed is very light, about 11 million kg⁻¹. One kg of fruit will yield about 600,000 seeds. The seeds can be separated from the fruits by drying them in the

sun, and then putting the crushed fruit into water, when the seed will sink and the husks float. They are then dried in the sun and stored in sealed plastic bags. It is said that the seed germinates better after 9–12 months storage to after-ripen it. M.W. Campbell (1983a) recommends storing the whole fruit for nine months, and then breaking it up directly on to the seed beds. Germination takes 3–6 weeks. The percentage germination is often low (4–11 per cent (R.V. Singh, 1982) though M.W. Campbell (1983a) suggests 30–40). However, this is relatively unimportant, as the seed is produced in very large quantities.

Nursery treatment

The seed should be sown in seed trays, using the techniques suitable for other small seeds. The seedlings should be pricked out into containers when they have developed two pairs of true leaves. They will be large enough after 3–5 months in the nursery for planting in the field. In India stumps have been used, though not apparently recently. To raise stumps a longer period in the nursery will be needed, at least one year, and the seedlings should be pricked out into transplant beds at a spacing of about 10 to 20 cm.

Rate of growth

This varies considerably with soil conditions, trees in natural forest having a mean annual diameter increment ranging from 2 to 8 mm. No information is available for growth in plantations.

Uses

The timber is yellowish, with a fine even grain. It is moderately durable. It is used for carving, bobbins, furniture, panelling and household fixtures, and is one of the species preferred by Newari wood-carvers in the Kathmandu Valley. It weighs about 670 kg m^{-3} and has a calorific value of about $27,000 \text{ kJ kg}^{-1}$. It burns steadily and has no undesirable properties as a fuelwood. In India the leaves are considered to be a medium-quality fodder; the tree is heavily lopped for this purpose. The crude protein ranges from 8.7 to 12.5 per cent, and fibre from 12.1 to 13.8 per cent; total digestible nutrients are about 5 per cent.

Importance in Nepal

Not much planted, though the timber from natural forests is valued. It is used on a small scale as fodder but is not of great importance.

References: M.W. Campbell (1983a); Chaturvedi *et al.* (1986); Gamble (1922); Ghosh (1977); Indian Timbers (1968c); Lamichhaney and Joshi (1980); Letourneux (1957); Magini and Tulstrup (1955); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

***Aesandra* Pierre**

Sapotaceae

***Aesandra butyracea* (Roxb.) Baehni**

(Syn. *Bassia butyracea* Roxb., *Madhuca butyracea* (Roxb.) Macbride)

Nepali: chiuri.

A fairly large tree, with a milky sap. Leaves crowded near the ends of the branches, tapering to the stalk, rounded at the apex, with prominent veins. Flowers white, 1.2–2.5 cm across, in clusters below the leaves. Fruit fleshy, ellipsoid, about 2 cm long. It is valued as a source of vegetable butter, and is often planted for this. A minor fodder.

Natural occurrence

It is found in Nepal from the Terai to 1500 m; as it is valued for its fruit it is often found outside the forest near farms. Its range has probably been extended by planting. Outside Nepal it grows in the Himalaya from Kumaon to Arunachal Pradesh.

Silvicultural characteristics

It is a light-demanding species with some tolerance to frost, and has been successfully planted from 600 to 1700 m. Even on poor stony soils survival has in most places been fairly good, but on such sites its growth has been slow.

Artificial regeneration

Seed

The fruit ripens between June and August; as it is of commercial value it will usually be necessary to buy either trees from which seed can be collected, or the fruit itself. In the latter case care must be taken to buy only freshly collected fruit, as the seed loses its viability within 2–3 days. The ripe fruit is yellow in colour. Loss of viability is hastened if the pulp is removed, so this should be done immediately before the seed is sown. The fruit should not be allowed to dry out. There are 100 fruits kg⁻¹, and 450 to 1000 or more seeds kg⁻¹. The germination percentage of fresh seed is high, between 50 and 80. Germination begins in 1–2 weeks, and may continue for four weeks. One nursery reported producing 600 plants from two *mana* (about 1 l) of seed.

Nursery treatment

The seed should be sown immediately after collection, after removing the flesh. It is sown directly into polypots, at the rate of two per container, and should be

sown horizontally. The seedlings benefit from shade during germination but the shade should be removed once they are 2–3 cm tall. However in frosty areas shade may be needed at night to protect the seedlings. They develop strong taproots, and regular root pruning is necessary. This should begin before winter, and continue after winter at monthly intervals. The pots should be spaced out with 5–10 cm between the rows after winter. Growth in the nursery is rather slow. Below 1000 m one year in the nursery is required to produce plantable seedlings, which should then be between 25 and 40 cm high. (The date of sowing is governed by the very short viability of the seeds.) Above 1000 m two years in the nursery will be needed.

Plantations

The use of seedlings in polypots is the recommended procedure. Some success has been claimed for 'bare-root planting' (seedlings raised in polythene pots, and then removed from them, and their roots soaked in muddy water) in Ridi division (Fujiwara, 1982). Survival, eight months after planting but before the end of the dry season, was 70 per cent. There may well have been more casualties before the onset of the rains. Tyystjarvi (1981) reports that this technique was also successfully used in Pokhara division. Removing the seedlings from the pots before transport is not true bare-root planting, and is not a good practice.

The use of large planting pits, one metre cubed, gave rather better growth in Dolakha District (Neville, 1987c). These pits gave 75 per cent survival, and a height growth of 31 cm, after two years, compared with 69 per cent survival and 18 cm from the use of the normal 30 cm cubed pits. Even so growth rates are very slow. For valuable trees such as *Aesandra butyracea* farmers might be prepared to use special measures, such as larger pits and the use of compost at the time of planting.

Performance in plantations and rate of growth

Early growth rates are slow. In plots designed to establish cutting banks, which were well tended, with the soil cultivated to 20–30 cm depth, and the equivalent of 400 kg ha⁻¹ Complexol (20:20:0) fertilizer added, the mean height at both Hetauda (474 m) and Chalnakhel (1370 m) was only 30 cm (Napier and Parajuli, 1987). Results elsewhere are similar. At Chirtungdhara (800 m) trees 30 months old averaged 50 cm in height and at Murtidhunga (1500 m) at 24 months the trees only averaged 18 cm high. In a four-year-old plantation in Tansen District the trees were about 60 cm high. Subsequent growth may be faster, as Gamble (1922) reports 3–4 rings per inch (2.5 cm) of radius, or a mean annual diameter increment of 1.3–1.7 cm. Troup (1921) reports a section 33 cm in diameter under bark with 46 rings, or a mean annual diameter

increment of approximately 0.7 cm, excluding the time needed for the seedling to grow to the height of the section.

Uses

The main use of *Aesandra butyracea* in Nepal is as a source of vegetable butter (*chiuri ghee*) obtained from the fruits. This butter is used for burning in lamps, in sweetmeats, and for soap manufacture. The cake obtained after extraction of the fat is toxic as it contains saponins; it is used as a fish-poison by the Chepang. The fat is also used for rubbing on chapped skin (Gajurel and Vaidya, 1984). The wood is a good fuel, weighing from 640 to 830 kg m⁻³. The leaves are a good fodder, and are quite widely used in some areas, for instance in Lalitpur District, where they are the most important source of fodder in April on south-facing slopes between 1000 and 1500 m (Upton, 1990).

Importance in Nepal

It has been in high demand from community forestry nurseries because of the value of its fruit. Generally it has survived quite well, which indicates that people value it enough to look after it. In the Community Forestry Development Project survival as a whole was 64 per cent, which compares quite well with other species tried (J.G. Campbell and Bhattarai, 1983b). According to Gajurel and Vaidya (1984) the Chepang people give *Aesandra butyracea* saplings as a dowry to their daughters. One district in west Nepal is reported as producing 27,000 *dharni* (about 68 t) of the *ghee* each year. However its slow rate of growth when young is a disadvantage.

References: M.W. Campbell (1983a); Gajurel and Vaidya (1984); Gamble (1922); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Troup (1921).

Aesculus L.

Hippocastanaceae

Aesculus indica (Colebr. ex Cambess.) Hook.

Nepali: kandar, karu, naru, pangre, lekh pangre, pangar, lampate, phangus.

Indian horse chestnut.

A large deciduous tree with a short bole. Leaves opposite, digitately divided into 5–9 serrate edged leaflets. Flowers handsome, in upright clusters. Fruits

large, with a smooth husk containing one, rarely two, dark brown polished seeds. Fairly important for timber, but a poor forage.

Occurrence

In Nepal it is confined to the west of the Kali Gandaki River, between 1200 and 2700 m, being commonest between 1900 and 2400 m. It is characteristic of moist sites near streams in forests of *Pinus roxburghii* and *Quercus leucotrichophora*. Outside Nepal it extends as far west as Afghanistan.

Silvicultural characteristics

It drops its leaves between December and April. It is a moderate light-demander; the seedlings will survive under heavy shade, but their growth is slow. Very light shade, however, seems to benefit them. It prefers rich deep soils with good water availability, and cool sites; on dry hill slopes it is stunted and unhealthy. It has some resistance to frost, though frost damage has been reported; it will not withstand drought. It coppices well and produces root suckers. The seedling produces a stout fleshy taproot, which may reach a length of 15 cm or more before the aerial parts appear; by two months old the taproot may exceed 30 cm in length.

Natural regeneration

The seeds are heavy, and after falling in October and November often roll into depressions where they become covered in leaves and earth. If unprotected by leaves and litter the seeds germinate in the following spring, but the radicle soon dries up and the young seedlings die; if the seeds are protected, however, the seedlings rapidly establish themselves. The trees are not usually gregarious, but natural regeneration is sometimes plentiful in moist ravines, and among loose soil and boulders on small landslips, if these occur on moist cool slopes.

Artificial regeneration

Seed

The seed ripens in January in the Far Western Development Region, but elsewhere it may fall from September onwards; local checks should be made of ripening dates. The ripe seed is shiny and dark brown in colour. It can be separated from the leathery capsule at the collection site. There are between 35 and 90 seeds kg⁻¹. The seed is recalcitrant, and must not be allowed to dry out. It can be stored for 4–5 months if kept moist, cool and aerated. This may be done by mixing it with two to four times its volume of damp sand, putting it in a fine wire-mesh bag or clay pot with a lid, and burying it in a pit 1–1.5 m deep. Alternatively the seed may be sown immediately after collection and left in the

soil to germinate next spring. Both methods provide moist cold stratification, which improves germination. In either case protection against rodents is essential. In India the germination capacity of fresh seed is said to be between 70 and 90 per cent. Germination in spring usually begins 3–4 weeks after sowing, and may be prolonged over a fairly long period.

Nursery treatment

The recommended method is to sow directly into extra large polythene pots, at least 4 inch x 7 inch (10 cm x 18 cm). The seed if stored over winter should be sown in February or March. A good potting mixture is needed, and if the soil is heavy or infertile about 20 per cent compost should be added. As the seedlings develop they should be spaced out with 5–10 cm between the rows. They soon develop strong taproots so frequent root pruning is essential. The seed is recalcitrant so there is little flexibility in the sowing date. Growth in the nursery is, however, rapid and at lower elevations seedlings should be large enough in four or five months to be planted out in the monsoon after sowing; elsewhere a further year in the nursery will be needed. Stumps should be raised in beds, into which the seeds are dibbled 15 cm apart in drills 30 cm apart; pricking out is unnecessary. At lower elevations the plants will be large enough for planting in the monsoon. Again protection against rodents is important. Similar techniques can be used for raising bare-root seedlings.

Plantations

Planting container-raised seedlings has no particular features except that larger planting pits than normal would be beneficial. Thorough weeding is essential. *Aesculus* is one species for which bare-root planting has been reasonably successful. In Darchula 30–45 cm bare-root seedlings are normally used; they will survive even if some roots are broken (Wilson, 1987). However the plantations should be over 1500 m, and not more than 1.5 hours walk from the nursery. Survival rates are 60 to 85 per cent. J. Stewart (1983a) reports good results in Doti from digging up wild seedlings up to a metre in height and planting them in pits. Survival at the beginning of the next rains was 80 per cent. Winter planting might also be tried in the Far Western Development Region, as it is a method used in adjacent parts of India. Stumps have been successful in India. Direct sowing in plantations has failed in India, because the seeds are eaten by rodents. However in Mahakali Forest Division direct sowing has been successful (Margolis, 1982). The seed should be sown soon after collection, that is in winter, in prepared pits; germination may not occur until the next spring.

Performance in plantations and rate of growth

Early growth is slow. According to Troup (1921) the seedlings should reach a height of 60 cm or more by the end of the first season after planting, but records available in Nepal show slower rates than this. Growth is also very much affected by altitude and site quality; on poor sites and at high altitudes it can be very slow indeed. At Simkhara (2400 m) trees 2.5 years old averaged 23 cm in height, with 65 per cent survival, and near Lumle on an area of gently sloping land at 2300 m, eight-year-old trees only averaged 35 cm in height (R.K. Shrestha and Gautam, 1991). At various elevations between 1900 and 2300 m near Lumle survival ranged from 45 to 64 per cent. No precise information is available from lower altitudes. Ring counts in India indicate that 45 years are needed for a tree to reach 20 cm in diameter.

Uses

The wood is white, soft and fine-grained, suitable for building, boards, mathematical instruments, and for turning into cups and bowls. It is a reasonably good fuelwood, weighing about 500 kg m⁻³. The leaves are not a very good fodder, and the tree is lopped in India only in times of scarcity. It is used in Nepal for bedding for cattle and compost. In India the nut is fed to sheep and goats, and also eaten by humans, after soaking in water, in times of scarcity (Gamble, 1922). However it is not a good food, as it contains saponins, and is used in pharmacy as an astringent and narcotic; there is a small trade in the nuts for medicinal purposes in Nepal (Manandhar, 1980).

Importance in Nepal

It was originally specified as a priority species by the Community Forestry Development Project, but in fact, it is only grown on a reasonably large scale in a few districts in the Far Western Region of Nepal, notably in Dadeldhura and Mahakali (Margolis, 1982; Monger and Margolis, 1982). As it is somewhat demanding in its site requirements it is more suitable for individual planting by farmers than for larger-scale planting.

References: M.W. Campbell (1983a); Ghosh (1977); H.B. Joshi (1981); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Margolis (1982); Monger and Margolis (1982); Napier and Robbins (1989); Suri and Seth (1959); Troup (1921).

Agati grandiflora see *Sesbania grandiflora*.

***Ailanthus* Desf.**

Simarubaceae

***Ailanthus excelsa* Roxb.**

Nepali: maharukh.

A large deciduous tree. Leaves pinnate, crowded at the ends of the branches, over 30 cm long, with an even number of pointed, toothed leaflets over 5 cm broad. Flowers small, greenish yellow, in much-branched clusters. Fruiting carpels surrounded by a wing, 4–8 cm long. A native to India, it is worth trialing for its rapid growth.

Occurrence

Indian peninsula, often planted elsewhere. Not indigenous to Nepal.

Silvicultural characteristics

It is capable of growing on poor soils under relatively low rainfall, down to about 800 mm; susceptible to frost. In India it is used for afforestation of poor sites, though on shallow soils its growth is poor. It does not grow well on clays or waterlogged areas. It is a strong light-demander. It coppices well and produces root suckers.

Artificial regeneration

In northern India the seed ripens in April. The seeds are separated from the wings by beating and winnowing. There are about 10,000 seeds kg⁻¹. The seed should be stored in sealed plastic bags. It is said to lose its viability in less than a year; M.W. Campbell (1983a) reports 10 per cent germination for fresh seed, and 5 per cent for seed one year old, but in India 60–80 per cent germination has been recorded (R.V. Singh, 1982). As germination is unreliable the seeds should be sown in trays or beds and the seedlings pricked out into polypots. Seedlings should be planted out at 4–5 months. Older plants give poor results (Ghosh, 1977). As there are some difficulties in raising seedlings, the use of cuttings, which root readily, might be preferable. Stumped plants are not satisfactory.

Rate of growth

Growth is rapid. At Butwal (150 m) trees 2.5 years old averaged 6.5 m in height by 8 cm in diameter.

Uses

The wood is soft and light, weighing 340–450 kg m⁻³. It can be used for packing cases, and makes good match splints. The mature leaves are a good fodder for sheep and goats, though young plants are not readily browsed by sheep, probably because of their offensive odour. The leaves may be dried for feeding later. Their crude protein content is about 20 per cent, and the digestibility coefficient fairly high. The yield of green fodder is reported to be high.

Importance in Nepal

So far it has only been planted on a trial scale. Its main value would be as a fodder species for low altitudes, and for matches. Its wood is too light to be a good fuel.

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); R.V. Singh (1982); Troup (1921).

Albizia Durazz.

Mimosaceae

Nepali: siris (general)

Thornless trees with bipinnate leaves. Flowers in globular clusters, with very long exserted numerous stamens. Pods flat, straight, thin.

Key to Nepalese species

- (1) Midrib of leaflet more or less central, more than one third the width of the leaflet from the upper margin; leaflets more than 2 cm long 2
- (1) Midrib of leaflet near upper margin; leaflets usually small 5
- (2) Apex of leaflets pointed 3
- (2) Apex of leaflets rounded 4
- (3) Pinnae one, rarely two pairs; leaflets usually two pairs, rarely more, 7–15 cm long by 3–7 cm broad; terminal pair of leaflets much larger than the others; flowers yellow or cream in much branched clusters; pods shining .. *A. lucidior*
- (3) Pinnae 2–3 pairs; leaflets 2–7 pairs, 3–12 cm long by 1.5–4 cm broad; terminal pair of leaflets at most slightly longer than the basal pair; flowers creamy white *A. gamblei*

(4) Bark light yellow or greenish grey, fairly smooth; pinnae 3–6 pairs; leaflets 4–12 pairs, 2–6 cm by 1.5–3 cm; flowers white, in up to 30 cm long much branched clusters; pods yellow-brown when ripe *A. procera*

(4) Bark dark grey, rather rough; pinnae 2–4 pairs; leaflets 4–10 pairs, 2–6 by 1–3 cm; flowers greenish white; heads solitary or in groups of 3–4 in the leaf axils; pods dark red brown when ripe *A. lebbeck*

(5) Pinnae 5 pairs or less; leaflets 6–18 pairs, 1–3 by 0.5–1.3 cm; apex of leaflets rounded; flowers white, heads in much branched clusters *A. odoratissima*

(5) Pinnae 6 pairs or more; apex of leaflets pointed; leaflets usually much smaller 6

(6) Leaflets 2 mm wide or less, midrib almost fused with upper edge; pinnae 7–12 pairs; leaflets 18–35 pairs, 0.6–0.8 cm long; young leaves with prominent ovate stipules 2–3 cm long, which soon fall off; flowers greenish or yellowish white *A. chinensis*

(6) Leaflets more than 3 mm wide; midrib close to upper edge of leaf but clearly separate from it; pinnae 4–8 pairs; leaflets 10–18 pairs, 0.6–2 cm long; stipules inconspicuous; flowers pink *A. julibrissin*

Note: Storrs and Storrs (1984) have good illustrations of the leaves of *A. chinensis*, *A. julibrissin* var. *mollis*, *A. lebbeck* and *A. procera*.

Albizia chinensis (Osbeck) Merr.

(Syn. *A. stipulata* (Roxb.) Boiv.)

Nepali: siran, sirin, rato siris, kalo siris.

Occurrence

From the Terai to about 1500 m, being characteristic of the upper *Shorea robusta* forests, especially near streams and in swampy places. It has not been collected from west of latitude 83°E in Nepal, though in Pakistan it extends as far west as the Indus; to the east it extends as far as Burma and the Malaysian Peninsula.

Silvicultural characteristics

A deciduous tree with a wide, spreading crown. It grows in the Kathmandu Valley, and hence probably shows some resistance to light frosts, but will not tolerate heavy frost. It is a moderate light-demander; the seedlings will withstand some shade but are killed by heavy shade. It prefers moister sites.

Natural regeneration

The pods begin to ripen in November to December, and continue to hang on the branches throughout the dry season. They usually fall before releasing the seed, and are carried about by the wind, which thus helps in seed dispersal. Regeneration is best on loose soil, with a fair degree of moisture; it is said to tolerate a moderate growth of grass and weeds. The trees can colonize other forest types, provided the shade is light.

Artificial regeneration

Seed

Seed should be collected after the pods have turned light brown in colour, and should be collected from the tree, not from the ground. There are about 3000 pods and 20,000–70,000 seed kg⁻¹. The seed can be stored for a year, but the germination percentage falls in this period; it should be dried and stored in sealed polythene bags, with a contact insecticide added to prevent borer attack. Before sowing the seed should be manually scarified or treated with hot water, by immersing it for two to three minutes in water that has boiled and been removed from the heat, and soaking it in cold water for 24 hours. A germination percentage of about 50 should be obtained, but much lower figures have been recorded.

Nursery and plantation techniques

The seed should be sown direct into polypots at the rate of two per pot. Surplus seedlings should be pricked out as soon as the first pair of pinnate leaves has appeared, as this species, like all *Albizia* species, tends to produce a long taproot. At Hetauda (474 m) 12 weeks in the nursery produced seedlings 15 cm tall, which is a little too small for planting out. Probably 16 weeks would be adequate at this altitude. Regular root pruning is needed once the roots have reached the bottom of the polypot. Shade is only necessary for protection against hail or heavy rain. Stumps from two-year-old seedlings have been used successfully in India.

Performance in plantations and rate of growth

There have not been many trials. At Butwal (140 m) trees 18 months old had 69 per cent survivors, with a mean height of 4.6 m and a dbh of 4.0 cm. For this site survival is rather low, but growth is reasonably good, better than that for *Dalbergia sissoo*, for example. At higher altitudes results have been rather disappointing. For example, at Kadambas (1450 m) at 40 months survival was 54 per cent and mean height 88 cm. In India isolated trees have grown very rapidly, with a mean annual diameter increment of up to 5 cm; in natural forest, a mean annual diameter increment of 2.7 cm has been recorded. However,

when growing naturally *A. chinensis* has a very large spreading crown, which under plantation conditions would tend to be restricted, and thus lower rates of growth are to be expected. In Java mean annual increments of 10–12 m³ ha⁻¹ have been recorded on good sites.

Uses

The timber is soft, and not very durable; the heartwood is light brown. It is used for light furniture and planking. It weighs from 300 to 550 kg m⁻³ and hence is rather light to be a good fuelwood. The sapwood can be used for match-splints, but the heartwood for boxes only. According to Panday (1982) it is a reasonably good fodder with a high crude protein content. One hectare with 300–400 trees should produce about 2 t yr⁻¹ dry matter. However R. V. Singh (1982) states that its digestibility is rather low, and that prolonged ad lib feeding to sheep gave rise to toxic symptoms. He gives a total crude protein value of 15 per cent (32 per cent digestible) and total digestible nutrients of 38 per cent. The gum is used for sizing *Daphne* paper. The tree has been used as a shade tree for tea.

Importance in Nepal

The limited trials carried out so far suggest it is best suited to fairly fertile sites at low altitudes.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhaney and Joshi (1980); Magini and Tulstrup (1955); Napier and Robbins (1989); National Academy of Sciences (1979); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Troup (1921); Venkataramany (1968b).

Albizia julibrissin Duraz.

Nepali: rato siris.

Two varieties occur in Nepal. Var. *julibrissin* has leaflets 6–10 mm long, which soon become glabrous, while var. *mollis* (Wall.) Benth. ex Baker (Syn. *A. mollis* (Wall.) Boiv.) has leaflets over 10 mm long which have appressed hairs on both surfaces. The former variety is rather rare and what follows mainly concerns var. *mollis*.

Occurrence

Up to 3000 m and down to below 1000 m. At its lower elevations it tends to occur near streams, and is a characteristic species of the Riverain Forest with *Shorea robusta* and *Mimosa rubicaulis*, and the Riverain Forest with *Cedrela toona* and *Albizia mollis* of Dobremez (1976). At higher altitudes it occurs in

Quercus leucotrichophora forest and elsewhere. Outside Nepal it extends from Kumaon to western China; it is often planted as a shade tree in tea gardens.

Silvicultural characteristics

It is a deciduous tree with a wide spreading crown, usually growing under rather moist conditions. It has some tolerance to frost, but in frosty areas seed from trees growing at higher altitudes should be used. It coppices well and produces numerous root suckers.

Artificial regeneration

Seed

The seed is generally collected between November and January, though there may be local variations; it should be collected as soon as the coat is hard. There are about 24,000 seeds kg^{-1} . Seed of var. *julibrissin* has an extremely long viability, up to 100 years or more, but it is not known how far var. *mollis* shares this character. However there should be no difficulties in storing it. It should be scarified or treated with hot water before it is sown directly into polypots, at the rate of two seeds per pot. Germination percentage should be between 50 and 90, but some Nepalese nurseries have reported much lower figures, down to 7, using two-month-old seed; possibly the seed was stored badly or not treated before sowing.

Nursery and plantation techniques

At 1300 m seedlings took between five and six months to reach a height of 15 cm which is a little on the small side for planting out; probably at this altitude August to September sowing would be preferable.

Performance in plantations and rate of growth

Not much information is available. At Murtidunga (1500 m) after two years, survival was 52 per cent and mean height 59 cm, which is poor. At 2000 m, in the same general area, it failed altogether. In India, in natural forest, growth is fairly rapid; the mean annual diameter increment is 1.0–1.6 cm.

Uses

The heartwood is dark brown and ornamental, and is used for furniture; it weighs about 700 kg m^{-3} . The fodder has a crude protein content of about 24 per cent (D. Bajracharya *et al.*, 1985) but the newly flushing leaves are harmful. Its pink and white flowers are very ornamental.

Importance in Nepal

It has been raised in some community forestry nurseries, but not on a large scale, though it may be lumped together with other *Albizia* species in reports. In Ilam Forest Division it was regarded as 'acceptable' by the local people, but its performance in plantations there was poor (Olsson, 1983). Although it grows naturally at the highest altitude of all Nepalese *albizias*, and is reported to be fast growing, its performance in Nepal has so far not been encouraging.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Napier and Robbins (1989); Rao and Purkayastha (1972); Troup (1921); Tyystjarvi (1981); Venkataramany (1968b).

Albizia lebbeck (L.) Benth.

Nepali: kalo siris.

Trade name: kokko.

Occurrence

From the Terai to about 1200 m, but commonest at lower altitudes. It is a constituent of Dobremez' (1976) Riverain Forest with *Dalbergia sissoo* and *Acacia catechu*, and his *Shorea-Terminalia tomentosa* Forest (Siwalik Phase). Outside Nepal it is widely distributed, from India to China and southeast Asia, and grows under rainfalls from 600 to over 2500 mm. It has been widely planted in tropical countries.

Silvicultural characteristics

It is a deciduous tree with a wide spreading crown when grown in the open. The seedlings will withstand some shade, but grow best under full sunlight. It will tolerate some frost, though in Nepal frost is rare in the area of its natural occurrence. *Albizia lebbeck* is not demanding on the soil—in India it is frequently planted on poor sites and for erosion control—but grows best on good, well-drained loams, as do most trees. It suffers greatly from browsing. It coppices well, and will produce root suckers if the roots are exposed.

Natural regeneration

The pods hang in large numbers on the branches; they fall while still containing the seed, so wind is an important agent for local dispersal. Insect damage to the fallen seed may be severe and this is blamed for poor natural regeneration in parts of India.

Artificial regeneration

Seed

In Nepal seed is collected between November and January, occasionally in February, but this may have been from pods which had remained a long time on the tree. There are between 5000 and 10,000 seeds kg^{-1} . About 880 pods weigh 1 kg and this will yield about 300 g of seed. The seeds should be dried in the sun and stored in sealed plastic bags, after any damaged or insect-attacked seeds have been removed. Germination is said to improve after storage for 2–4 years, but satisfactory germination (50–60 per cent) has been obtained in Nepal from fresh seeds. The viability of stored seed is very long, even seeds stored for 30 years show five per cent viability. However, the seed is susceptible to bruchid attack which may occur while the pods are still on the tree, so a little contact insecticide should be mixed with the stored seed. The seed should be scarified or treated with hot water before sowing. In Nepal from 1900 to 6700 plants have been obtained kg^{-1} of seed.

Nursery and plantation techniques

The seed should be sown directly into polypots, two seeds being sown into each polypot. The seedlings should have full light, except when shade is necessary to protect them from hail or very heavy rain. Frequent root pruning is necessary. Below 1000 m plantable seedlings can be obtained after 4–5 months in the nursery, from sowing in February–March; but at higher altitudes 9–12 months will be needed. In India raising plants as stumps has been successful. The stumps should be 8–13 mm thick at the root collar, that is about the thickness of the little finger, or a little smaller, with about 4 cm stem and 20–25 cm root. Such plants need to be raised in beds for 12–15 months before stumping. Napier (1987b) suggests that for planting by farmers, large plants up to 1.5 m tall should be tried, each planted with a ball of earth, as is customary in India. A brief description of how to raise such plants can be found in the chapter on Nurseries in Volume 1 of this manual. There are reports from outside Nepal of successful propagation by cuttings, but a series of attempts at the Farm Forestry Project at Hetauda to propagate the tree by branch cuttings failed.

Performance in plantations and rate of growth

At Butwal (140 m) at the age of 30 months there were 100 per cent survivors, with a mean height of 3.5 m and dbh 3.1 cm; at Sagarnath (100 m) at 21 months the mean height was 4.5 m and dbh 4.9 m. These growth rates are reasonably good, but at both sites other species did better. These are on fairly good sites; on poorer sites growth will naturally be slower.

Uses

The heartwood is dark brown with black streaks and is very decorative. It is used for buildings, furniture, parquet flooring, carts, agricultural implements and rice pounders. It weighs about 680 kg m^{-3} at 12 per cent moisture content. The heartwood is durable but the sapwood is liable to borer attack. Its fuelwood is of high calorific value about $27,000 \text{ kJ kg}^{-1}$, and burns slowly, but the smoke irritates the eyes. The leaves are reported to be a good fodder, with 17–26 per cent crude protein; 100 kg of leaves yield 11–12 kg of digestible protein, and 37 kg of digestible carbohydrates (R.V. Singh, 1982). The new flush of leaves may be injurious, and in Nepal other species are preferred for fodder. It has a number of medicinal uses.

Importance in Nepal

It has been raised in a number of community forestry nurseries, but is not in great demand. It is most suited for altitudes below 1000 m, and has been planted as an avenue tree in the Terai. It might find a place for planting on poor eroded soils, in view of its widespread use in India for this purpose, but rapid growth is not to be expected on such sites.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Indian Timbers (1970); Lamichhane and Joshi (1980); Mader and Stewart (1983); Magini and Tulstrup (1955); Napier and Robbins (1989); National Academy of Sciences (1979; 1980); Olsson (1983); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921); Tyystjarvi (1981); Venkataramany (1968b); Webb *et al.* (1984).

Albizia lucidior (Steud.) I. Nielsen ex Hara

(Syn. *A. lucida* Benth.)

A native of Nepal, in the centre and east, from the Terai to about 1500 m, usually either near streams or in the high rainfall areas of eastern Nepal. It is used for afforestation in Assam, but has not been planted in Nepal. There are about 11,000 seeds kg^{-1} ; they lose their viability quickly, and should be sown immediately after collection.

References: Gamble (1922); Rao and Purkayastha (1972); R.V. Singh (1982); Troup (1921); Venkataramany (1968b).

Albizia mollis see *A. julibrissin* var. *mollis*.

***Albizia odoratissima* (L.f.) Benth.**

Native to Nepal, up to about 1000 m. It has not been planted here as far as is known but it has been used for plantations in India. The seed ripens in January to February and there are about 16,000 seeds kg⁻¹. In India about 7000 plants can be raised from 1 kg of seed. Stored seed retains its viability well. Nursery techniques are similar to those for other *Albizia* species. Its growth rate is comparable with that of *A. lebbeck*. It is used in Nepal as a fodder species (Panday, 1982).

References: Gamble (1922); Ghosh (1977); Panday (1982); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Troup (1921); Venkataramany (1968b).

***Albizia procera* (Roxb.) Benth.**

Nepali: seto siris, dun siris.

Occurrence

In Nepal from the Terai to 1350 m, often associated with *A. lebbeck*. Outside Nepal it extends from the Jamuna (Jumna) River to Burma. It often occurs on alluvial soil near water courses.

Silvicultural characteristics

Albizia procera prefers moist alluvial sites and swampy places; it will grow on clay soils in such conditions. It is a light-demander, though the seedlings will withstand some shade. Frosts cause it considerable damage. It coppices well. The branches are liable to be broken by strong winds. The seedlings appear to be very sensitive to grass competition. It is deciduous for a short time during the hot season.

Natural regeneration

The twigs become covered with masses of pods which turn red during the cold season. They dehisce before or about the time they fall, unlike those of some other *Albizia* which tend to fall with the seeds. Germination takes place readily, and numerous seedlings may be found round the seed bearers during the rainy season. If shade is dense the seedlings soon die off; also, in densely shaded places, some of the seed may not germinate until the second rains. Seedlings may be found in abundance on new alluvial ground near streams, but they also occur quite plentifully in moist grassy tracts.

Artificial regeneration

Seed

The seed ripens from December to January; the ripe pods are dark brown or nearly black. There are 18,000–24,000 seeds kg^{-1} . The seed should be dried in the sun and stored in sealed plastic bags with some insecticide added to prevent borer attack. It retains its viability well; seed stored for 15 years has given 20 per cent germination, and in Nepal, under field conditions, four-year-old seeds gave about 40 per cent germination. In India between 11,000 and 16,000 plants have been raised from 1 kg of seed. The seed should be manually scarified or treated with hot water before it is sown.

Nursery and plantation techniques

Plants are normally raised in polypots. Two treated seeds should be sown directly into each pot, surplus plants being later pricked out into empty pots. Below 1000 m the seed should be sown in March, at higher elevations in August to September. Stumps have been used successfully in India, and also large plants up to 150 cm tall planted with balls of earth. In Darchula District in the Far Western Development Region bare-root plants have been used, but with only moderate success, between 30 and 50 per cent survival. They should be less than 35 cm tall, and the occurrence of post-planting rain is important. The plants often die back after planting, but will shoot again from the base. Here also tall seedlings up to 100 cm have been planted successfully while dormant in winter. The Far Western Development Region tends to have more winter rainfall than other regions, and hence winter planting is often more successful there than elsewhere. This species is very susceptible to grass competition, and plantations need thorough weeding.

Performance in plantations and rate of growth

Performance in trials in Nepal has been rather patchy. In some there has been good growth but in others survival and growth has been poor. Early trials at Chitripani and Adabhar failed, but this was before the importance of clean weeding in this area was realized. Results in community forest plantations in Ilam District were poor. Results are available from other trials (Table 21, page 382).

In the better trials growth exceeded that of *Dalbergia sissoo*. In all the lowland trials *Eucalyptus camaldulensis* grew faster. Outside Nepal growth is said to be rapid under good conditions, with a mean annual diameter increment exceeding 1 cm. Plantations have given a mean annual increment of about $11 \text{ m}^3 \text{ ha}^{-1}$ in Burma.

Table 21—Performance of *Albizia procera* in plantation

Site	Age (months)	Survival (%)	Mean height (m)	dbh (cm)	Remarks
Butwal (140 m)	18	96	4.8	4.8	
	30	94	3.9	3.5	
Shankarnagar (150 m)	17	98	2.8	6.6 ^a	unpruned
		98	3.0	5.7 ^a	pruned
Sagarnath (100 m)	20		2.5		
	21		1.9		
	22		3.4		
Banduk, Myagdi (1450 m)	29	98	1.5		

Note: (a) diameter at 10 cm above ground level

Uses

Its timber is similar to that of *A. lebbeck*, and is used in general construction, and for carts and furniture. The sapwood weighs about 460 kg m⁻³ and the heartwood 640 kg m⁻³. It has a calorific value of 26,800 kJ kg⁻¹ but produces irritant smoke; it makes good charcoal. The leaves are a fairly good cattle fodder, containing about 17 per cent crude protein (D. Bajracharya *et al.*, 1985)

Importance in Nepal

It has been raised in a few community forestry nurseries, but is not in great demand. It might have a role in better sites in the Terai and Bhabar Terai as a multipurpose fodder, timber and fuelwood tree.

References: M.W. Campbell (1983a); Chaturvedi *et al.* (1986); Gamble (1922); Lamichhane and Joshi (1980); Napier and Robbins (1989); National Academy of Sciences (1979); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921); Tyystjarvi (1981); Venkataramany (1968b).

Albizia stipulata see *A. chinensis*.

Exotic species

Albizia caribaea

Introduced from Honduras. Tried at Adabhar in 1985, but after 17 months survival was only 32 per cent, and growth poor. Not successful.

Albizia falcataria (L.) Fosberg

(Syn. *A. falcata* (L.) Backer; *A. moluccana* Miq.; *Paraserianthes falcataria* (L.)

In the constantly humid tropics, without a pronounced rainy season, this is considered to be one of the fastest-growing trees in the world, with a mean annual increment of up to 50 m³ ha⁻¹. However it is much less suitable for areas with a pronounced dry season. This has been confirmed by trials at Adabhar, where survival was only 27 per cent, and growth moderate. Unsuitable for Nepal.

Reference: Neil (1990d).

Albizia guachapele

Introduced from Guatemala in 1985 and planted at Adabhar. After 32 months survival was 92 per cent, mean height 4.6 m, mean dbh 4.4 cm. Merits further trial. There are 17,000 viable seeds kg⁻¹. In nurseries in the Terai 9–13 weeks is needed to reach plantable size.

References: Neil (1990d); Westwood (1985).

Alnus L.

Betulaceae

Alnus nepalensis D. Don

Nepali: utis.

Alder.

Deciduous tree. Bark silvery grey with raised lines of prominent lenticels. Leaves alternate, elliptical, with prominent parallel veins. Male flowers in drooping catkins; females in axillary clusters. Fruits cone-like, black, about 1.5

cm long. A common and often gregarious species of the Middle Hills of Nepal, much used locally as small building timber.

Natural occurrence

It has a wide range in Nepal, descending as low as 500 m, but most common from 900 m upwards. Its extreme upper limit is about 2700 m. Particularly at lower elevations it is characteristic of moist sites such as near rivers and in ravines but it is also a colonist of shaly and gravelly land exposed by landslips, and of abandoned cultivation. Outside Nepal it is found in the Himalaya as far west as Kumaon, and in the east it reaches to Upper Burma.

Silvicultural characteristics

A pioneer species which grows well in full light. It does not require high soil fertility but prefers moist permeable soils and should not be planted on hard eroded soils. It grows well on soils with a high water content, but not if they are completely waterlogged. Although in nature it is commonest near streams and in other wet places, it can be planted on other sites; it has, for example, done well when planted in open grazing land on south-facing slopes near Pokhara, at about 1500 m, (admittedly an area of exceptionally high rainfall), and on abandoned cultivation terraces near Pakhribas at about 1700 m on north-facing slopes. However, it does badly on dry, exposed, ridge-top sites.

Young seedlings are defoliated by frost, and very often killed. At Pakhribas 70 per cent of the seedlings planted at 1900 m on an exposed south-facing slope were killed by cold. However as it occurs naturally up to 2700 m, it would be worth trying high-altitude provenances in frosty areas. It is liable to damage by browsing animals when young, but seedlings over 50 cm high are relatively immune (Schaltenbrand, 1982). Reports of its ability to coppice differ; some say it coppices well, others that it will not coppice. These differences may be due to the locality, or possibly the time of year in which it was cut. Trees cut about 60 cm above ground level will put out shoots. All *Alnus* species have a symbiotic association with species of *Frankia*, an actinomycete, which forms root nodules which fix atmospheric nitrogen.

Natural regeneration

The seed is produced in abundance; it is winged, and dispersed by the wind as the cones are shaken. The tree colonizes landslips and abandoned cultivation.

Artificial regeneration

Seed

The seed is collected between November and March, according to the locality, when the cone-like fruits turn brown and begin to open. Abundant seed is produced most years. The cones should be collected when they are brown, just before they open, by cutting off small cone-bearing twigs. The seed is extracted by drying the fruit in the sun, and shaking out the seeds. One tree should yield at least 1 kg of fruits. About 8 kg of fruit give 1 kg of seed. There are between 400,000 and 2,300,000 seeds kg^{-1} , depending on how well the seed has been cleaned, as generally the seed is mixed with a good deal of chaff (wings); the higher figure refers to seed without chaff. In practice it is unnecessary to separate the seeds from the chaff.

If the seed is dried thoroughly, put in sealed containers, and stored in a refrigerator at 4–5°C it will keep its viability for a year or more. Where refrigerated storage is not possible, sealed plastic bags should be used. In these there is a gradual loss of viability to about 75 per cent after six months and 25 per cent after a year. Seed stored in cloth bags loses its viability completely within three months. The seed should be put into the containers immediately after drying, as it reabsorbs moisture very quickly, and must never be left exposed overnight (Napier and Robbins, 1987).

Reports from nurseries in 1981 showed very low germination percentage from *A. nepalensis* seed (Sharpe, 1982), but this can be attributed to poor seed storage and probably poor nursery techniques. Answers to a subsequent questionnaire in 1982 gave rates as high as 30 per cent, with the number of plants raised from 1 kg of seed averaging about 30,000 (disregarding some nurseries where very bad results were obtained); 113,000 plants kg^{-1} was the highest figure. No pre-treatment is needed before the seed is sown.

Nursery and plantation techniques

For raising plants in polypots the seed should be sown in trays or beds, at the rate of 20 g m^{-2} , and covered with a layer of sand just deep enough to cover the seed. In warm weather germination begins after 1–2 weeks and should be complete in three weeks, but in cold weather it may take much longer. The newly germinating seedlings should be kept under shade, and protected against heavy rain by plastic sheeting. Young seedlings are very delicate and regular watering is essential. The water, however, should be enough to keep the surface of the seed bed moist and no more, as constantly wet conditions are also harmful. See also methods for small-seeded species, in the chapter on Nurseries in Volume 1 of the manual.

After 4–5 weeks, when the seedlings have put out three or four true leaves, they should be pricked out into polypots and again be kept under shade until

they are well established, usually in 2–4 weeks. Roots may need to be trimmed when the seedlings are pricked out. As long as the potting soil is not too heavy or infertile, compost is not needed. Below 1200 m the seed should be sown in early March, and the seedlings spaced out with 5–10 cm between the rows at the end of May. Above 1200 m the seed should be sown in August, and the seedlings spaced out in March of the next year. The aim is to produce seedlings 25–35 cm tall.

The seedlings do not develop a strong taproot and root curl in the polypots is not a great danger, though regular root pruning should not be neglected. It is possible, though not to be recommended as routine, to use oversize seedlings in plantations; cutting the tops back to leave the stems 25–30 cm high is advisable. Young seedlings are liable to damage by ants, and insecticide treatment may be needed. The use of fertilizers on the nursery seedlings will not often be necessary. It has been found that heavy applications of nitrogen are harmful (Sharpe, 1984c). If nitrogen fertilizers are used at all, they should be applied as a top dressing in water, and not incorporated into the potting mixture.

The possibility of using bare-root plants instead of plants in polypots has aroused a great deal of interest, mainly to avoid difficulties of transporting large numbers of potted plants using human labour. Results from trials have been very variable. In the IHDP area at Jiri, bare-root plants succeeded in initial trials, when the work was well supervised, but failed on a more extensive scale when close supervision was no longer possible (Grunenfelder, 1980a). More recent trials by IHDP have given very bad results, and the technique is no longer used. It also failed at Pokhara in 1981 where bare-root plants had a survival rate of only 2 per cent, compared with 58 per cent for polypot-raised seedlings (Grob, 1982). In a replicated experiment at Pakhribas the survival of seedlings raised in polypots was 100 per cent, while that of bare-root plants was 75 per cent (averaged over three storage treatments). The differences in survival were not statistically significant. The trial was in a year of particularly favourable conditions (P.R. Pradhan, 1982b).

In the south of Lalitpur District bare-root plants are provided to farmers as a routine. The nursery is at 2000 m on a ridge top which is almost permanently covered in mist from May to October, as are most of the planting sites. The seed is sown just before the monsoon, and the seedlings pricked out into raised beds at 5 cm x 10 cm spacing. In the following March to June roots and shoots are pruned at monthly intervals, and the beds shaded for several days after each pruning. The plants are lifted at the end of June and roots and shoots again pruned back, and immediately packed into plastic bags for transport. It is impressed on the farmers that the seedlings should be planted as soon as they reach the planting site; if not possible they should be heeled in. Farmers realize

that cool northern slopes are best suited to *A. nepalensis*. Nine months after planting mean survival was 87 per cent (Iles, 1988). Bare-root plants have also performed well in Ilam District, provided the work is supervised well (Olsson, 1983). They have also been used routinely in Darchula District, possibly from necessity rather than choice, due to difficulties in raising polypot stock. Here seedlings less than 50 cm tall have given 50–80 per cent survival, but those over 50 cm less than 30 per cent. The method has only been successful at altitudes over 1500 m, not more than 1.5 hours walk from the nursery (Wilson, 1988).

In general it appears that bare-root plants can only be relied on in areas of high rainfall and high atmospheric humidity, and then only if the work can be well supervised. Elsewhere polypot plants are much more reliable. Wildings (natural seedlings) collected from the forest have been successfully used in Ilam, either planted out directly, or first planted in the nursery. Seedlings 12–15 cm high are used, with their roots well protected by polythene and watered soil during transport (Olsson, 1983).

The Lamosangu-Jiri Road Project has had considerable success by broadcasting seed on eroded areas and exposed soils caused by road-building works, and some thriving young stands can now be seen along this road. Other areas have been established by the Department of Roads. In some other areas results have been poorer, and broadcasting on landslips failed in the Tinau Watershed Project (Schaltenbrand, 1982). In the Trisuli Watershed Project seed was sown in prepared pits. Some plants grew, but others failed either because the seed was sown too deep or because it was washed out by rain (Hirsbrunner, 1968?). To establish *A. nepalensis* stands by broadcasting, the seed must be fresh and have a high germinative capacity, and ample quantities should be used. The sowing should be on exposed mineral soil.

In general winter planting has not given satisfactory results. In a provenance trial at Pakhribas survival from winter planting (February) averaged 48 per cent, while summer planting (July) gave 98 per cent, despite the fact that the seedlings of some provenances were very small (Lamichhaney, 1984). The following results (Table 22, page 388) were obtained from a replicated experiment to study the effect of dates of planting, also at Pakhribas (data modified from P.R. Pradhan, 1982b). There were no significant differences in the survival percentages between June, July and August plantings. These trials were made at two sites, one at 1800 m and one at 1400 m. In the September planting survival at 1800 m was 90 per cent, but at 1400 m it was only 24 per cent. In yet another trial at Pakhribas at 1700 m, after one year there was 100 per cent survival from trees planted in May, June, August and September; 50–60 per cent in October and November, and 8 per cent in April. Thus certainly in the Pakhribas area, in eastern Nepal, winter planting has failed.

Table 22—Survival and height growth of *Alnus nepalensis* planted at different times of the year

Time of planting	Survival (%)	Mean height (cm)
End February	26	298
End April	2	401 ^a
End June	81	223
End July	93	188
End August	90	159
End September	57	133

Notes: (a) only one survivor. All measurements were taken in the November after the year of planting.

Performance in plantations and rate of growth

In general trials over about 2200 m have failed, but between 1000 m and 2200 m survival and growth are more influenced by factors such as soil depth, water availability, aspect and exposure than by altitude alone. For example, in Parbat District, Western Development Region, at 1800 m seven-year-old trees planted on a gentle to moderate slope were 13.4 m tall, whereas those on a very steep slope were only 3.5 m tall. (The steepness of the slope in itself probably has little effect on growth, but steep slopes will have shallower and more stony soils than gentle slopes.) Growth on hot, south-facing slopes is usually poorer than on other aspects.

On good sites growth rates are generally fast. At Pipal Chaur, in a mixture of planted trees and natural regeneration, aged eight years and less, the largest trees were 14.6 m in height by 19 cm dbh; there were dense clumps of trees in the between 10 and 15 cm dbh. For trees over about three-years-old, on very good sites, a mean annual height increment of a little less than 2 m can be expected, declining on poor sites to 0.5 m or less. At Kaskikot in the Phewa Tal Watershed near Pokhara a six-year-old plantation produced a mean annual yield of wood of 4.3 t ha⁻¹, but this was a plantation where other species had been mixed with *A. nepalensis* and were later suppressed by it. It is estimated that from a fully-stocked pure plantation a mean annual yield of 6 t ha⁻¹ could be obtained (Kharel and Mulder, 1983; Mulder, 1983a). At 1800 m in the Darjeeling Hills, India, ten-year-old trees reached 17 m in height by almost 30 cm diameter (Troup, 1921).

General volume tables are included given in E.R. Sharma and Pukkala (1990b). Harrison (1989c) gives a table of fuelwood production against

diameter, and equations for calculations of stem, branch, and foliage biomass are given in B. Thapa *et al.* (1989a).

Provenances

In a species such as *A. nepalensis*, which grows under a wide range of climatic conditions, differences between provenances from various parts of Nepal are to be expected. Lamichhaney (1981; 1984) collected seed of *A. nepalensis* from trees in twelve localities in Nepal, and found significant differences in seed weight, the rate of growth of seedlings in the nursery, and other factors. Seedlings of the different origins were planted in trials in Pakhribas. The results after one year were strongly influenced by the size of seedling at the date of planting, which ranged from 3.7 to 23.4 cm. However, 28 months after planting the best height growth, on the whole, was from provenances from eastern Nepal (in which Pakhribas is situated), while provenances from the far west of Nepal had the poorest height growth (Clark, 1985). It is to be expected that local provenances will perform best on a given site, as they are adapted to the ecological conditions of that site. There are exceptions to this rule, and it is desirable that provenance trials should be continued. Even within a single region provenances giving superior growth, for that region, may be found. In particular, the frost tolerance of different provenances should be studied further.

Pests and diseases

Alnus nepalensis is very subject to attack by defoliators, one of which is *Oreina* sp. (Chrysomelidae) (Anon., 1981b; 1982a; 1982b). Large trees soon recover from this attack but the growth of seedlings may be severely retarded. Seedlings planted in the Phewa Tal catchment area near Pokhara in 1979, which were severely defoliated in 1980, had not grown to 1 m in height by 1983 (Mulder, 1983b). Control in this area was affected by spraying the trees with a 0.1 per cent solution of metacid, but this sort of treatment is clearly impracticable on a large scale. For larger trees a band of insecticide may be painted round the trunk (R. Lewis, 1978).

At Pakhribas a shoot borer has been recorded which bored into the leading shoot and caused the shoot to die back for between 30 and 60 cm. A stem borer was also recorded which attacked the tree about 30 cm from the base, killing some of the less vigorous trees (about two years old). The incidence of stem-borer attack varied from 23 to 61 per cent, for different provenances (Clark, 1985). Neither species of insect has been identified, but the larva of a Cossid moth, *Zeuzera* sp., has been recorded as a stem borer elsewhere in Nepal (Ivory, 1985). There would not seem to be any practicable control against this sort of

attack; also the effects of stem borer on subsequent growth are unknown. Certainly there are some very good *A. nepalensis* stands at Pakhribas despite the occurrence of these insects. Two leaf rusts have been recorded but do not appear to cause significant damage (Adhikari and Manandhar, 1989).

Uses

The wood is rather light, 320–370 kg m⁻³ (National Academy of Sciences, 1980); 430–450 kg m⁻³ (Gamble, 1922). Its calorific value is relatively low, at 18,230 kJ kg⁻¹ (Hawkins, 1982). Thus it is not a very good fuel from the point of view of kilojoules per cubic metre, though this is compensated for by its high volume increment. It dries rapidly and burns easily. Although it is not considered to be the best construction timber, it is very important in the Middle Hills for small timbers such as rafters, and door and window frames. It has been tried for matches (Dey and Ramaswami, 1960) and for paper. The mature leaves are eaten by sheep and goats, but not cattle (Panday, 1982). The seed has been sown broadcast to stabilize landslips. In eastern Nepal it is widely used as a shade tree for cardamoms.

Importance in Nepal

Despite the shortcomings mentioned above it is widely planted in Nepal, mainly because of its rapid growth, good form and the relative ease by which it can be established. It is very popular among farmers; in Salle village in Dhankuta District in the Middle Hills of eastern Nepal the average number of *A. nepalensis* trees per farm was 259, and every farmer had some (B. Thapa *et al.*, 1990). It is also one of the trees most favoured by farmers for planting in many parts of Nepal, mainly as a source of fuelwood, small timber, and in the east as a shade tree for certain crops. It is a useful species for planting in ravines and other small areas near farms where crops cannot be grown.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane (1992); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); National Academy of Sciences (1980); Neil (1990); R.V. Singh (1982); Troup (1921); Webb *et al.* (1984).

Other species

Alnus nitida (Spach.) Engl.

In Nepal this is a rather rare species, occurring along the Mugu Karnali in the Humla region at about 2100 m, and perhaps elsewhere in the west. It extends to Kashmir. It has been tried in a few places. At Tistung (1800 m) its growth was

comparable with that of *A. nepalensis* though neither species grew very well. At Salle, Dhankuta District (2000 m) it had 90 per cent survival and a mean height of 87 cm after two years; while at Simkhara (2400 m) both survival and growth were poor. In the nursery the seedlings grow faster than those of *A. nepalensis*, and may be pricked out about three weeks after germination has begun. Below 1200 m seed should be sown in late March, above 1200 m in December. So far there is not enough information to judge its future importance.

References: Napier and Robbins (1989); Troup (1921).

Alnus glutinosa (L.) Gaertn., *A. hirsuta* Rupr. (syn. *A. tinctoria*), *A. inokumae* and *A. rubra* Bong. were also tried at Tistung on a poor site for *Alnus*. *Alnus rubra* was clearly unsuitable, and the performance of the others was little different from that of *A. nepalensis*. *Alnus hirsuta* failed at Kharidunga (2400 m).

Anogeissus Wall.

Combretaceae

Anogeissus latifolius (Roxb. ex DC) Bedd.

Nepali: banghi, bajhi, daura.

A large tree with drooping branches. Leaves alternate, broadly elliptic, 4–9 cm long. Flowers in spherical heads 6–8 mm in diameter. Fruit small, two winged. It occurs in Nepal from the Terai to about 1700 m, usually in *Shorea robusta* forest. It is also a common constituent of rather dry forest in the Siwaliks, particularly in western Nepal, where it is sometimes dominant. The tree is a strong light-demander; it has some tolerance to frost, but is rather unpalatable and not greatly damaged by browsing. If it is cut in April or May it coppices well, but fails to put out shoots if coppiced during the rains. The best season for pollarding is not later than March. It produces root suckers.

The leaves turn reddish about November, and fall about February. New leaves are put out in April to May. The seeds ripen in December to March; they are dispersed by winds. Although abundant seed is produced annually, much of it is often infertile. Seedlings are often produced in abundance on newly exposed soil, especially when it is well drained. The seed should be collected when the fruit heads begin to break up, about February. There are 100,000–120,000 seeds kg⁻¹; the viability is about 15 months. Germination rates are reported to be 25 per cent for fresh seed, but in India germination is often poor,

and it is suggested that the germinative power may vary with the season (Troup, 1921). Germination may take up to six weeks. The seed should be sown in beds or trays, and the seedlings pricked out into containers when they are 2–3 cm high; the plants need about a year in the nursery, and hence the seed should be sown about June. The seedling has a strong taproot. The species can also be raised from stumps. On the whole, however, *Anogeissus* has been little planted; it has occasionally been used on poor dry sites in India. The growth rate is moderate. Trees in a forest garden in India averaged 9 m in height by 15 cm in diameter at 15 years old; in natural forest the mean annual diameter increment is about 7 mm.

It is a good fuelwood (specific gravity about 0.72; 27,000 kJ kg⁻¹), though its smoke irritates the eyes. Its timber is hard and tough; it is not durable in contact with the ground, but is reasonably durable in buildings. It is a preferred timber in India for tool handles, and is widely used for carts and ploughs. It is used as a fodder in India, the leaves containing between 7.5 and 11.5 per cent crude protein. In India they are also harvested for tannin.

References: M.W. Campbell (1983a); Chaturvedi *et al.* (1986); Gamble (1922); Lamichhane and Joshi (1980); National Academy of Sciences (1980); Rao and Purkayastha (1972); R.V. Singh (1982); Trotter (1958); Troup (1921).

***Anthocephalus* A. Rich.**

Rubiaceae

***Anthocephalus chinensis* (Lam.) A. Rich. ex Walp.**

(Syn. *A. cadamba* (Roxb.) Miq.)

Nepali: kadam.

A large deciduous tree with horizontal branches. Leaves opposite, 12–23 cm long, broadly ovate, shining above, pubescent beneath. Flowers yellow in globular heads 3.5–5 cm in diameter. Fruit fleshy, about 5 cm diameter, with numerous small capsules inserted in the flesh. It is native to Nepal from the Terai up to about 1000 m, usually in moist areas near streams in *Shorea robusta* forest. It tolerates some shade in early life, but saplings become spindly if kept under shade too long. It is sensitive to frost and is very liable to be browsed. It grows best on deep alluvial soils with a good water supply, and in these conditions its growth is very rapid. It coppices well. The fruits are eaten by cattle, birds and animals such as fruit bats, and the seeds are dispersed in this manner. Young seedlings are often produced in dense masses, but they are very

small and are liable to be washed away by heavy rain. They are sensitive to drought, but in very damp conditions they suffer a good deal from damping-off.

In India the fruit ripens from November to February, though in West Bengal it may ripen as early as August; the time of ripening in Nepal should be checked locally. The ripe fruits are orange in colour. The very small seeds (900,000–2,700,000 seeds kg⁻¹) are extracted by macerating the fruit in water; they are then dried in the sun. Dry seed can be stored for a year in sealed containers, though the viability is said to fall during storage. Fresh seed gives about 80 per cent germination. The seed should be sown in beds or trays, using the techniques for sowing small seed, and the seedlings pricked out into polythene pots when they are 2–3 cm tall. Seed sown in February–March should provide plantable seedlings by the break of the monsoon.

On deep soil with a good water supply, and in the constantly humid tropics, its growth can be extremely rapid, but it is much poorer on less favourable sites. The only records from trials in Nepal are from Butwal (140 m) where after 18 months, survival was 97 per cent, mean height 5.9 m and dbh 8 cm; in another trial after 30 months, survival was 94 per cent, mean height 6.9 m and dbh 6.3 cm (Neil, 1990d). In the first trial especially, these growth rates are very good, but Butwal is a good site, and before extensive plantations are made elsewhere small-scale trials should be carried out.

The wood is white and soft, weighing about 600 kg m⁻³. It is used for veneer corestock, matches and paper pulp. Air-dry wood yields about 23,000 kJ kg⁻¹ when burnt; it burns slowly, with no drawbacks except occasional crackling. The leaves are a medium quality fodder.

References: M.W. Campbell (1983a); Chaturvedi *et al.* (1986); J. Evans (1982); Gamble (1922); Ghosh (1977); Magini and Tulstrup (1955); R.V. Singh (1982); Troup (1921); Webb *et al.* (1984).

Artocarpus J.R. & G. Forst.

Moraceae

Artocarpus lakoocha Wall. ex Roxb.

Nepali: badhar, badahar, borran, bahar.

A medium-sized, occasionally large deciduous tree with a milky sap. Leaves alternate, 10–25 cm long, elliptical, pointed, rather leathery. Male and female flowers in separate spherical heads. Fruits 5–10 cm in diameter, irregularly

lobed. Good illustrations of the fruits can be seen in Panday (1982) and Storrs and Storrs (1984). One of the most valued fodder trees in Nepal.

Natural occurrence

It is found from the Terai to about 1300 m, occasionally to 1600 m in isolated, well-protected spots. In its wild state it often grows along the banks of streams. Its range has been considerably extended by planting. Rather strangely no authenticated herbarium specimens have been collected from Nepal and hence it is not included in the Enumeration (Hara *et al.*, 1982). Outside Nepal it extends westward to Kumaon in the Himalayan foothills, and it is also found in southern India, Sri Lanka, Burma and Malaysia.

Silvicultural characteristics

A deciduous tree, which drops its leaves for a short time at the beginning of the hot season. Young trees will withstand moderate shade, but older trees grow best in full light. It grows best on deep permeable soils with a good supply of moisture, and does not thrive on poorer sites. Young seedlings are badly damaged by frost, and the tree should not be planted in frosty areas. At moderately high altitudes many seedlings turn yellow in the cold period, and some die back; some of the seedlings which have died back will, however, eventually recover (Mulder, pers. comm.). Young plants are very liable to damage by browsing animals.

Natural regeneration

The fruits are greedily eaten by birds and monkeys, which scatter the seeds under the trees, where, after the rains, numerous seedlings may be found. (This assumes the fruits have not been previously gathered for human consumption.) Exposed seed usually does not germinate, and it is better if the seed becomes buried. Unless they are in moist and fairly shady conditions many seedlings die in the dry season.

Artificial regeneration

Seed

The fruit ripens between late June and early August in most localities, but there are considerable variations; local checks are advisable. When ripe the fruits begin to turn yellowish. As the trees are lopped for fodder, and the fruit has a market value, it is usually necessary to buy or rent trees to assure a supply of seed. As a rough guide one tree will yield about 80 kg of fruit and about 6000 seeds (Tengnas, 1981). It is also possible to buy fruit in the market, but some caution is needed, as the seed loses its viability rapidly. The seed from fruit

which is collected green and stored to ripen is also of low viability. Seed is sometimes more easily obtained in the Terai than in the hills, and in the Pokhara area it is frequently brought up from the Terai (Mulder, pers. comm.). There is some risk, however, of bringing in less well-adapted provenances if this method is used.

The seed is recalcitrant, losing its viability within a few days; it should be sown as soon as possible, and not more than two days after collection. It if has to be kept for a day or two it should be kept in the fruit until it can be sown. There are from 1900 to 5000 seeds kg^{-1} ; 18–25 fruits weigh 1 kg and there are 10–30 seeds in each fruit. The flesh should be removed from the seeds immediately before they are sown. At lower altitudes germination usually begins about two weeks after sowing, and is complete 1–2 weeks later; above 1500 m it may take longer. Fresh seed has a germination percentage of about 80. It should be possible to raise between 1000 and 2000 plants from 1 kg of seed.

Nursery and plantation techniques

Large polybags, 4 inch x 7 inch (10 cm x 18 cm) lay-flat should be used, with 20–25 per cent compost added to the potting mixture. The seed may be sown directly into the pots, at two seeds per pot; if more than one seed per pot germinates the surplus seedlings may be pricked out into another pot, or otherwise thrown away. The seeds should be covered with about 3 mm of soil, or a mulch. An alternative method is to sow the seed at the rate of 1 kg m^{-2} in raised beds; the seedlings should be pricked out when they are about 5 cm tall, 3–4 weeks later.

The short viability of the seed dictates the sowing date, just before the onset of the monsoon. This will produce plantable seedlings, which should be 20–25 cm tall or more, by the next monsoon. The seedlings are fairly robust, and two or three weeks after the seed has germinated, shade against sun and rain is no longer needed; however protection from frost is necessary where this is a hazard. The seed and young seedlings also need protection against rodents. A strong orange-coloured taproot is developed and frequent root pruning is necessary. This should begin in September or October, depending on growth. It is not necessary in winter, but should begin again in March, and repeated at least once a month, until the seedlings are planted out; during periods of rapid growth more frequent root pruning may be needed. Seedlings should be spaced out with 5–10 cm between the rows not later than March or April. Regular watering, once a day, preferably in the evening, is needed. In nurseries at higher altitudes the leaves may become yellow and the shoots die back during cold weather.

Stumps are reported to have been successful, but no details are available (Mader and Stewart, 1983). Root cuttings approximately 5 cm long from the

taproots of nursery seedlings have also succeeded (Mader and Stewart, 1983; Tengnas, 1981). According to G.B. Rimal (1984) best results are obtained from root cuttings taken in Chaitra (March–April). Early attempts to root stem cuttings were largely unsuccessful (Napier, 1988; Sharpe, 1984c; Tyystjarvi, 1981), but later, at Hetauda, A.V. Parajuli (1988) succeeded in rooting 46 per cent of cuttings taken in March, and 31 per cent in February. Best results were from cuttings 20 cm long, with at least three buds, taken from the lower part of the stems of 1.5-year-old seedlings.

Planting techniques

This is a tree which needs a good deal of care and attention. As it is likely to be used mainly by individual farmers planting a few trees on their farms, more elaborate methods of planting and maintenance than those used for routine plantations may be justified. Neville (1987c) compared the use of pits 1 m x 1 m x 1 m, with the normal 30 cm x 30 cm x 30 cm pits, in Dolakha District at 1360 m. After two years, in the normal pits survival was 44 per cent and mean height 15 cm, compared with 85 per cent survival and a height growth of 30 cm in the larger pits. Certainly this is an improvement, but a height of 30 cm in two years is not very good. However at Chirtungdhara (800 m) after 16 months there were no significant differences in height and survival between plants (a) without fertilizer, (b) with 25 g complexol per plant, and (c) with added compost; survival ranged from 87 to 93 per cent, and mean heights from 60 to 65 cm. These results are not very conclusive, but continued trials of simple methods usable by farmers would be useful. For plants near their houses they might even be prepared to water them from time to time.

Performance in plantations and growth rates

Growth in early years is rather slow, and decreases with the altitude. One of the best results was at Hetauda, where plants 18 months old averaged 1.6 m in height, on ground which had been weeded and thoroughly cultivated to a depth of 20–25 cm, and to which 20:20:0 fertilizer had been added at the rate of 400 kg ha⁻¹. These are near to optimum conditions. Elsewhere height growth at two years old ranges from about 1.1 m in the Terai to 30–60 cm at 1500 m. Above 1500 m, and in exposed places above 1300 m, growth is very poor. Later growth is faster. Timber specimens in India indicated a mean annual diameter increment of 13–17 mm, which is comparatively quick.

Uses

Its main value in Nepal is for fodder. Farmers prize it for its high nutritive value and good yield of leaves. They have a crude protein content of about 16 per cent, and are relatively low in tannins. The main collecting season varies with

the locality. In Bara District in the Terai the most important season is during the monsoon, followed by mid-December to mid-February, and the pre-monsoon period from mid-April to mid-June (Upadhyay, 1991). Near Dhankuta it is fed between mid-October and mid-January (Dutt, 1992). In Lamjung District mid-September to mid-November is the important period (K.P. Gajurel *et al.*, 1987). (The leaves fall between February and April, and the new flush is in the pre-monsoon period.) There are no adverse effects on animals' health at any time in the year. The tree can be lopped for fodder after it is about four years old. Panday (1982) describes a tree over 30 m high by 3 m in girth which was still giving a good yield of fodder after more than a hundred years of leaf harvesting. It was owned by four families.

Estimates of fodder yields vary considerably. Some are not very reliable, being based largely on farmers' estimates. One result based on measurements is from Kaski District where five trees with heights ranging from 10.6 to 23 m, average 14.7 m, and diameters from 22 to 72 cm, average 38 cm, produced yields of 36 to 270 kg of fresh matter, average 128 kg (Vaidya and Gautam, 1989). Sometimes the leaves of young trees are removed individually by hand, and branches are not lopped; this is partly because the small lateral branches are strong enough to bear the weight of a man climbing the tree (Panday, 1982).

The fruit is edible by humans, and is sold in local markets; a pickle is made from the young fruit, and in India the young male flower heads are also pickled (Gamble, 1922). The wood is hard, with a white perishable sapwood and a yellow heartwood which turns dark brown and is termite resistant. It weighs about 640 kg m⁻³. In India it is a valuable timber, but in Nepal because the tree is so highly valued for fodder and fruit its timber is not much used.

Importance in Nepal

In many parts of Nepal it is the fodder species most preferred by farmers. It is not, however, generally the most used, partly because other trees are commoner, partly because it is not a very easy tree to grow. Nevertheless it is in great demand for planting by farmers. Survival rates in farmers' plantations are very variable, ranging from 15 per cent after four years in the IHDP area to about 60 per cent after one year in the Community Forestry Development Project (J.G. Campbell and Bhattarai, 1983a). There is thus room for considerable improvement, but if this can be achieved *A. lakoocha* is a most valuable tree for Nepal. Because it requires fertile soils for good growth, and also quite a lot of care and attention, it is more suitable for planting by individual farmers than in community plantations.

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Panday (1984); Trotter (1958); Troup (1921).

***Artocarpus heterophyllus* Lam.**

Nepali: katahar.

Jack fruit.

There has been some confusion over the botanical name of the jack fruit, which is frequently referred to as *A. integer* (or *A. integra*) or *A. integrifolia*. These names correctly belong to the champedak of Malaysia (see below). It is assumed that references to katahar, *A. integra* and *A. integrifolia* in Nepalese literature are to the jack fruit. *Artocarpus heterophyllus* is mainly cultivated for its fruit, though the timber is of high quality. The leaves, and also the ripe fruits, are fed to cattle in India. Techniques for raising the seedlings are similar to those for *A. lakoocha*. The seed, however, is considerably larger, 45 to 90 weighing 1 kg, so the seedlings should be raised in large polythene pots. The seed loses its viability quickly, and should be sown immediately after collection. The tree is sensitive to drought, frost, fire and browsing.

References: Purseglove (1968); R.V. Singh (1982); Troup (1921).

***Artocarpus integra* (Thunb.) Merrill**

This species, the champedak, is recorded from eastern Nepal, at 200–1700 m, in Hara *et al.* (1982) but no other references to its cultivation in Nepal have been found. It can be distinguished from *A. heterophyllus* by its papery (not gelatinous) covering to the seeds, and the thin wiry brown hairs on its twigs.

References: Allen (1975); Purseglove (1968).

Arundinaria spp. see Bamboos.

***Azadirachta* A. Juss.**

Meliaceae

***Azadirachta indica* A. Juss.**

(Syn. *Melia azadirachta* L., *Melia indica* (A. Juss.) Brandis)

Nepali: nim.

Neem.

An evergreen tree, capable of growing to a large size. Leaves alternate, pinnate; leaflets toothed. Flowers white, about 8 mm in diameter, in branched clusters. Fruits fleshy, about 1.5 by 1 cm, ripening yellow, with a single kernel. Whole plant, especially flowers and fruit, has a strong mustardy smell.

Occurrence

Recorded from the Terai to about 900 m but doubtfully indigenous to Nepal, as it has often been planted. It is widespread in India, and extends to Burma. A subspecies is indigenous in Thailand.

Silvicultural characteristics

A light-demander, though seedlings can establish themselves under the shade of older trees and thorny bushes. It tolerates a wide range of soil types, except the heaviest clays, but growth is better on more permeable soils, even on almost pure sand. It withstands high temperatures and a long dry season; indeed in parts of Africa its growth is better with an annual rainfall of 700–800 mm than with 1000 mm or more. It is very sensitive to frost, and subject to damage by browsing. It coppices well.

Artificial regeneration

The seed ripens in June to July, and should be sown immediately, after removing the pulp, as the viability is short, falling rapidly after two weeks. There are between 3000 and 6500 depulped seeds kg⁻¹. Seedlings can be raised in polythene bags, 2–3 seeds being sown directly into each bag; such seedlings, however, will tend to be rather large for planting in the next monsoon, and it may be necessary to restrict growth by reducing the amount of water given them. Regular root pruning is necessary. An alternative is to use stumps, obtained by sowing the seeds about 5 cm apart in beds at the beginning of the monsoon. It may be possible to raise the stumps without artificial watering during the dry season. Stumps should have stems at least 8 mm diameter, and should be prepared with about 5 cm shoot and 20–25 cm root. If plants are

raised from stumps each may produce several shoots after being planted; excess shoots should be removed in the season after planting, during weeding or replacement operations.

Rate of growth

There are no data from Nepal. Elsewhere growth rates vary widely according to soil conditions; on first class sites in Africa annual increments of up to 20 m³ ha⁻¹ have been recorded (Gravsholt *et al.*, 1967).

Uses

The wood weighs between 560 and 850 kg m⁻³, and has a high calorific value of about 29,000 kJ kg⁻¹; it is a good fuelwood except for producing acrid and irritating smoke. Its timber is decorative and durable, although as *A. indica* is usually managed on a short rotation for fuel and poles, not much timber is produced. It is regarded as a good fodder tree, the leaves having a crude protein content of 12–18 per cent with a satisfactory digestibility coefficient (R.V. Singh, 1982). The tree has many other uses. The leaves contain azadirachtin, an insect repellent, and are put among clothes to keep moths away. The insecticidal extract is now being marketed commercially. The twigs are traditionally used as toothbrushes. The seeds produce an oil used for soap manufacture and in pharmaceuticals. There are also many uses in traditional medicine.

Importance in Nepal

So far it has been little planted. In many parts of the world it has been planted for fuelwood and small poles, and as a multipurpose tree. In India it has been widely used for reforestation of degraded and eroded sites, and might find an application on such sites bordering the Nepalese Terai. It could find a place in the Terai as a multipurpose tree for people to plant near their homes, but it should only be planted on low altitude, frost-free sites.

References: Bengé (1968); M.W. Campbell (1983a); Chaturvedi *et al.* (1986); Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Magini and Tulstrup (1955); National Academy of Sciences (1980); R.V. Singh (1982); Troup (1921); Webb *et al.* (1984).

Bamboos

Gramineae

by C.M.A. Stapleton¹

Occurrence and importance

Until recently little was known about the identity, distribution and uses in Nepal of the different species of bamboo. The standard reference, Gamble (1896), is not at all adequate for identification purposes in Nepal, and the herbarium specimens available are not well determined. This is understandable as Nepal has not been fully covered by bamboo taxonomists in the past, and also as accurate identification of bamboo specimens requires both flowers and vegetative material. As most bamboos do not flower frequently and many species drop all their leaves and culm sheaths when they do flower, these are not usually available together, so specimens are fragmentary.

A few publications have named species from Nepal, but often these have been more guesswork than accurate identification. However, Seeland (1980) studied the names and uses of the seven bamboo species known near a village in east Nepal and successfully identified the five most important. B.N. Acharya (1975) wrote a sensible feasibility study of bamboo as the basis of cottage industry expansion in central Nepal without attempting specific identification. He used the three categories into which bamboo species are most commonly grouped in Nepali: bans, nigalo and malingo. These three groups probably constituted a more rational taxonomy at that time than the official genera.

Since 1981 the Forest Research and Survey Centre has undertaken a programme of determining the distribution, local names and uses of major Nepalese species, along with their vegetative, and when available, floral features. Stapleton (1982) gave preliminary identifications of the eastern species, subject to the limitations imposed by the small area which was covered and the status of taxonomy at that time. An update of these species and a preliminary identification of the central and western species are given below. Mid-Western and Far Western Development Regions' species will be covered in due course.

It is recommended that until a comprehensive list of diagnoses for Nepalese species is published along with a means of field recognition, local names be used as much as possible. Different species are distinguished by those who use

¹ Revised for second edition by J.K. Jackson

them and though their names may not be altogether consistent, they can be backed up by a geographical reference. This is much more useful than guessing at a name incorrectly, or calling them all *Dendrocalamus strictus* (as Storrs and Storrs (1984) have misleadingly labelled a description that is accompanied by illustrations of both *Dendrocalamus* and *Bambusa* species).

The importance of bamboos in the rural economy of Nepal can hardly be over-emphasized. They are in great demand by farmers both for fodder and for many other uses. In many parts of the country practically every farm will have several clumps of bamboo. They are planted near buildings and on small areas of land which are, for various reasons, unsuitable for agriculture, such as gulleys, steep slopes and rocky sites. So far they have been planted mainly by individual farmers on their own land, but there is no reason why they should not be used on a larger scale in community forestry plantations. Once established they will produce an annual crop for many years.

Silvicultural characteristics

Bamboos are perennial grasses, with woody culms from rhizomes. The rhizomes may be short and thick (pachymorph), and clustered together, in which case they produce bamboos in well-defined clumps; this type of rhizome is found in all the larger Nepalese bamboos (*Bambusa* and *Dendrocalamus* species) and in most of the smaller Nepalese ones (*Drepanostachyum* and *Thamnocalamus* species). Species of *Arundinaria* have long thin (leptomorph) rhizomes which run parallel to the ground and produce isolated shoots at intervals of up to 3 m. Pachymorph bamboos may have a long neck between the main sections of the rhizome giving a very open clump. Extension of this neck may be facultative in some species.

Mature bamboo clumps produce new shoots every year throughout the rainy season. These shoots develop rapidly, and within two or three months reach their full height and diameter; the current year's culms are however much softer and less woody than older culms. The culms persist in the clumps if not cut for about 7–12 years, depending upon the species, dying slowly and being replaced by new culms. If older culms are not removed they restrict the development of the rhizome system and new shoots. Much greater productivity is obtained by thinning out the poles regularly. Species vary in the distance between poles. Those which naturally produce a more open clump are much easier to manage and thus more productive.

Bamboos vary greatly in their flowering habits. Some species flower only at long regular intervals of up to 120 years or more. It is a popular misconception that this applies to all bamboos. However, most bamboos flower at shorter, more irregular, intervals and sporadic flowering very frequently occurs within

a single clump or few clumps. Such sporadic flowerings have been seen in all the seven principal Nepalese *Bambusa* and *Dendrocalamus* species.

Another popular misconception is that clumps of all species always die after flowering. Production of large quantities of seed uses up great amounts of reserves which can lead to complete death of the clump, especially in situations of stress. However there is evidence both from experience in other grasses (D. Lewis, 1979), and from observation of *Dendrocalamus hamiltonii* in Nepal that many bamboos are self-incompatible and can only produce large amounts of seed when cross-pollinated. As most flowerings are sporadic, or involve clumps which are quite separated, completely effective cross-pollination does not usually occur. Consequently seed production is low and the clumps do not use up all their reserves. When many genetically different clumps flower close together cross-pollination is fully effective and the clumps will often die after producing great amounts of seed, especially at times of low rainfall and in areas prone to drought. Bamboo clumps in the Middle Hills are usually quite well separated, being interspersed with agricultural land. In addition genetic variability is low as they are usually propagated vegetatively. Consequently most flowerings should produce small quantities of seed and the clumps should not die. This has been borne out by experience in Nepal over three years, particularly with *Dendrocalamus hamiltonii*. However, it will be many years before the flowering habits of all Nepalese bamboos can confidently be predicted.

In Nepal most farmers have several different species of bamboos. This protects them against supply of products being interrupted by flowerings. Monocultures of single species of bamboos over large areas are not recommended both because of the potential disruption of supply and also because large rodent populations can build up after seeding and damage nearby food crops.

Propagation

Vegetative propagation: traditional

Bamboos have traditionally been propagated by vegetative means throughout their range. As far as is known Nepalese species were propagated entirely by vegetative techniques up to about 1975, after which a few organizations collected small amounts of seed of *Dendrocalamus hamiltonii* and some *Drepanostachyum* species. The traditional method used on *Bambusa* and *Dendrocalamus* species involves the preparation and planting of a bulky offset cutting, which comprises the whole or a subsequent part of a one-year-old rhizome section with a 1–3 m length of culm attached and which can weigh up to 40 kg. This method is very reliable if undertaken properly (Stapleton and Tamrakar, 1983a). A culm from the previous year should be removed along

with its entire rhizome and cut back to 1.5–2.5 m, see Figure 7. If the bamboo can be watered this can be done in March or April, otherwise in late May or early June during rainy weather. The rhizome should be protected from the sun (hence superstitions about the planter's shadow killing the plant) and buds or new shoots on rhizome and culm should not be damaged. A long pole puts foliage beyond reach of grazing animals, but shorter culms are easier to transport; however there should always be 2–3 nodes with an eye or branch.

The rhizome plus culm cuttings should be planted as soon as possible after they have been cut from the parent clump, preferably the same day. If this is not possible they should be dug into the soil temporarily. The size of the planting hole will depend on the size of the rhizomes, ranging from 40 cm x 25 cm for large bamboo such as *D. hamiltonii* to 15 cm x 10 cm for the smaller *Drepanostachyum* and *Arundinaria* species. In dry weather the bamboo should be well watered after planting. If long culms are used they may need to be tied to stakes to prevent them being shaken by animals or wind. Such culm and rhizome cuttings can also be planted in nurseries to produce mother stools from which subsequent cuttings can be made.

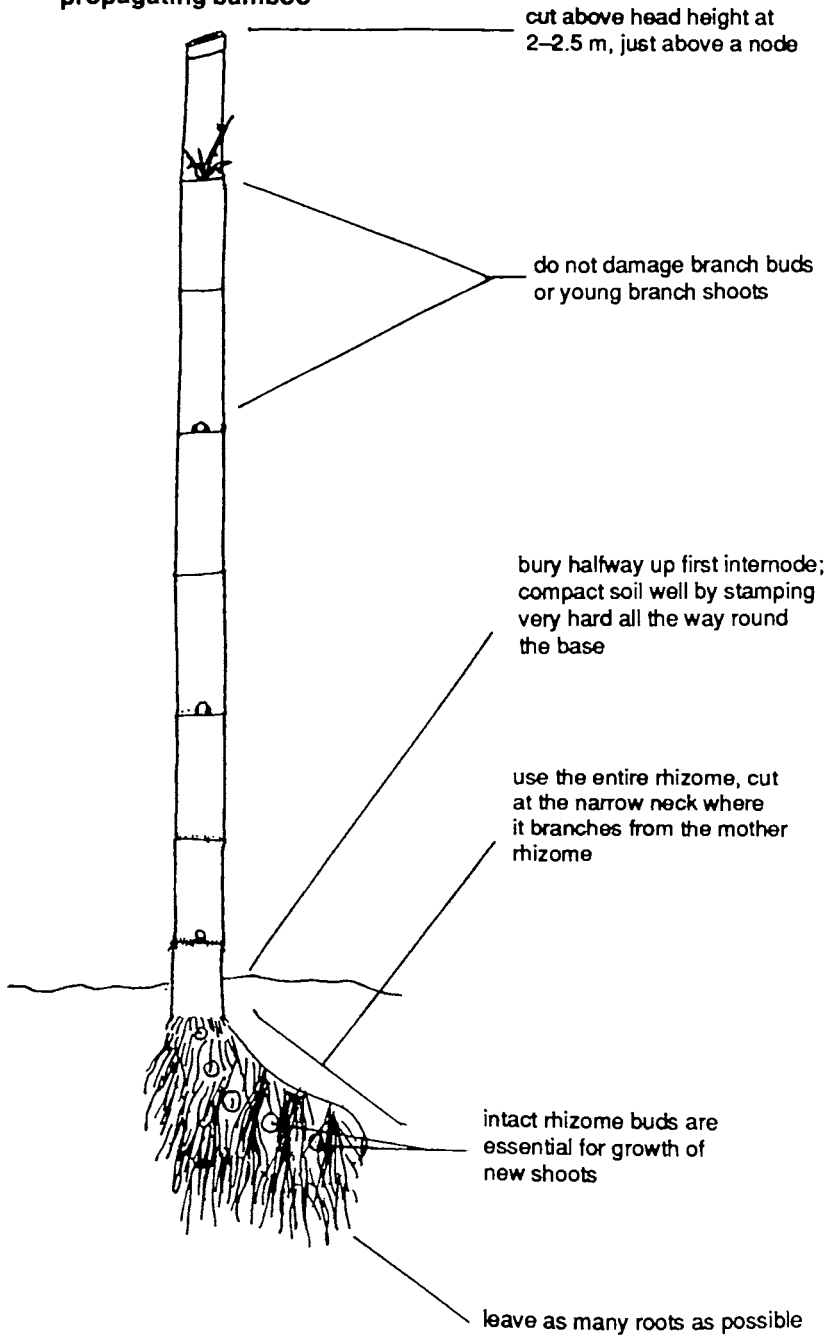
The effectiveness of this method, given sufficient time, is witnessed by the large amount of bamboo which is seen interspersed with agriculture and buildings and which has reportedly nearly all been planted in this way over centuries. Large blocks or plantations, however, are the exception rather than the rule, largely because of the short supply of planting material and the difficulty of transporting and planting more than a few cuttings. It has been widely reported that clumps planted vegetatively will flower at the same time as the parent clump and this has been seen in Nepal. However, as explained above, clumps do not always die after flowering, and if they do they are likely to produce seed or natural regeneration.

The first culms to arise from a good offset cutting can reach 4 m in the first year, whereas a good seedling will reach about 1.5 m maximum, so establishment from offset cuttings is usually at least two years quicker. With offset cuttings the advantages of quick establishment, robustness and independence of nursery facilities are set against the drawbacks of bulk, low availability, difficult extraction, transport and planting, and the possibility of imminent flowering.

For stabilizing road slopes trials have been made of using long offset cuttings with the culms placed horizontally and buried. However these have been reported to have produced shoots from the rhizomes only, and not from the nodes or branches, so the benefits from the technique would appear to be slight.

Offset cuttings from leptomorph bamboos need a longer length of rhizome than in pachymorph bamboos, so as to include sufficient rhizome buds and

Figure 7—Rhizome cutting: traditional method of vegetatively propagating bamboo



roots. It is reported that rhizome runners, without culms, can be used for these species.

Culm cuttings

There are many species which rarely produce seed and cannot be planted in quantity by the traditional technique but which are very important and desirable species for local planting programmes. Several species of *Dendrocalamus* and *Bambusa* have now been propagated by the use of small culm cuttings in nursery beds. In this technique branches are forced to grow in a manner which encourages the basal region to resemble a rhizome and produce roots (Stapleton, 1985a; 1986). This technique is still to a certain extent experimental and may need to be refined, but it has been very successful with certain species. The simpler technique described by M.W. Campbell (1983a) of planting pole sections without rhizomes directly under field conditions has usually failed in Nepal.

Cuttings which consist of a single node, with its branches cut back to 10–20 cm, and half the internode on each side are used in the new technique. This allows the branches to be oriented correctly and provides maximum reserves and maximum area for water intake at the cut culm ends for each node. When this technique is undertaken carefully each pole used can produce fifteen to thirty plants without having disturbed the rhizome system of the mother clump at all.

The best time for planting the cuttings is just before spring growth commences, when the buds are ready to burst. This obviously varies greatly with location and must be observed to determine exactly when it occurs. In hot places, such as the Terai, it may occur in February, while at 1500 m in the Koshi Zone it occurs in late March, and in the Kathmandu Valley as late as April. The culms should be cut between the nodes, leaves removed, and small branches cut off as close as possible to the culm. The central, largest, branch from each node should be cut off above the first extended internode. Cuttings should be dipped in water, or sprinkled immediately after they have been prepared, and kept moist during transport by pouring on water and covering with leaves or grass. They should be planted without delay on reaching the nursery.

In *Bambusa* species two- or three-years-old culms have given the best results. Culms with strong branching have been more successful than those with small branches, and cuttings from the top of the culm less than 4 cm diameter have usually failed. The stronger the branching the more the branch bases resemble rhizomes, and the more readily will the cuttings root. However some success has been obtained from culms with dormant buds, or where the central branch of the node has not yet developed.

The cuttings are placed in very well-watered, shaded beds with the large central branch horizontal at the soil surface, and the bud at the first node of the central branch facing upwards. The earth should be mounded up over the culm, especially at the ends, to reduce desiccation from sun and wind (see Figure 8, page 408). In two *Bambusa* species used it has generally only been shoots from the base of the central branch from each node which have rooted. Moreover the shoots which have developed downwards first and then turned up to reach the light have rooted much better than those which go upwards from the top of the branch.

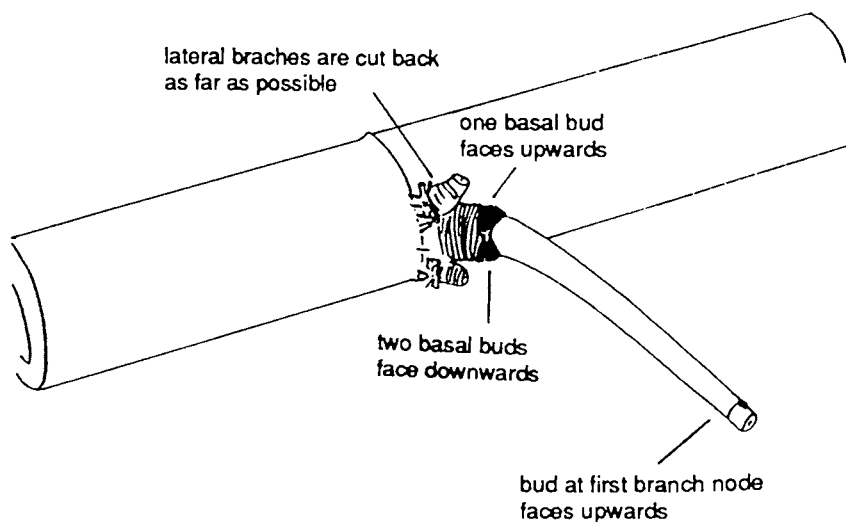
- In those *Bambusa* species which do not have aerial roots on the nodes of culms or from the bases of the central branches on the standing culm, the soil covering the ends of the culm cuttings must not dry out or the new shoots will die. Species which have such roots, such as *Dendrocalamus* species and some other *Bambusa* species can survive more arduous conditions. Root production is much more abundant overall in these species, and success rates have been much higher, with many nodes giving more than one rooted shoot.

If the cuttings obtain enough water from the beds and do not dry out, shoots will develop in one to two weeks. Most of those shoots will grow to about a metre in height and produce leafy branches before beginning to root after about three months. Irrigation and shading must be maintained all this time. Ironically it has been after the monsoon rain has started that cuttings have dried out in our trials, because nursery workers have ceased to take enough care over watering, assuming that the showers are providing enough water. Intense sun after a short shower quickly dries out the air and soil, and watering should continue unless continuous rain is falling. Watering and rainfall will remove the soil from the cuttings. This should be replaced. Encouragement of a ground cover of small weeds, mosses, etc. keeps the soil in place and indicates that watering is sufficient. Watering should continue after the monsoon and through winter to the planting season, but it is not so critical after roots have developed.

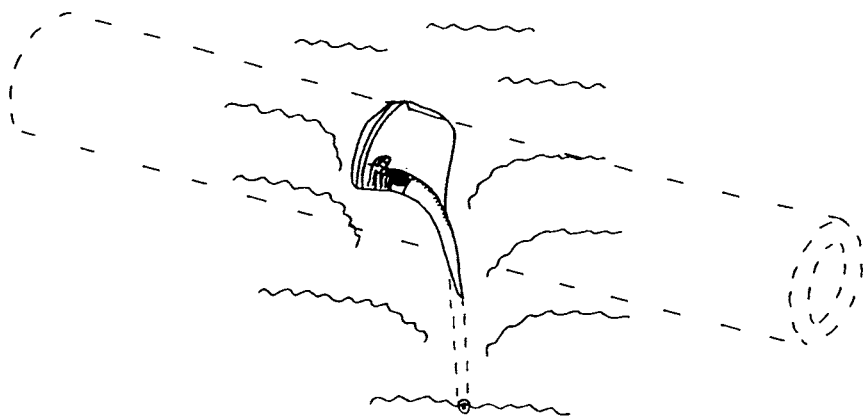
Below 1500 m the cuttings will need to be kept 16 months in the nursery; above 1500 m for a year longer. The plants must have shoots at least 2 m long before being planted out in the field. They can be cut back a little to ease transportation and reduce desiccation. More care is required than with plants in polypots as the root system is more disturbed during planting.

Dendrocalamus species have produced two or even three separate plants from some nodes. In addition some nodes may produce plants which break easily into two complete plants after 12 months. These can be planted separately. Sometimes two-noded cuttings have been used (Poudyal and McCracken, 1992); they say, however, that single-node cuttings are preferable for species with large branches. No results have been seen of comparative trials

Figure 8—Culm cutting for vegetatively propagating bamboo



Planting technique for prepared cutting of *Bambusa* species, with culm and branch horizontal and only the branch not covered by soil: (From Stapleton, 1985a.)



of the two methods. The following are the approximate rates of success from single-node culm cuttings from different species of bamboo.

- *Dendrocalamus hookerii* (kalo, bhalu bans) 80–100 per cent
- *Dendrocalamus hamiltonii* (tama, choya bans) 75–100 per cent
- *Bambusa balcooa* (dhanu bans) 70–90 per cent
- *Bambusa* sp. (tharu bans) 70–90 per cent
- *Bambusa nutans* (mal bans) <30 per cent

In addition the following have been recorded from species not listed in Stapleton (1987); sometimes two-noded cuttings were used.

- *Dendrocalamus giganteus* (bhalu bans) 60 per cent
- *Dendrocalamus* sp. (tama bans) (Kathmandu Valley) 90 per cent
- *Oxytenanthera* or *Bambusa* sp. (koraincho bans) 20 per cent
- *Bambusa glaucescens* (pahelo bans) 90–99 per cent (two-noded cuttings)

Raising bamboos from seed

Seed collection and handling

It is very fortunate that the widespread and useful species *Dendrocalamus hamiltonii* (tama bans) very frequently flowers in a sporadic manner. It is locally known that a flowering clump can be found in most areas at any time, and in many cases there are a few clumps within pollination distance and seed is produced. Small-scale gregarious flowerings have been seen, producing vast amounts of seed. Bamboos appear to be able to flower at any time of year and the production of flowers in an isolated flowering clump which does not quickly use up all its reserves by seed production can be continuous for up to three years or more.

In all Nepalese species in which seed production has been seen, the course of events in individual flowers from their first development through anthesis to seed falling has taken less than one month. Prompt falling of ripe seed causes difficulties in seed collection. Gathering branches rarely results in collection of seed, merely empty flowers and immature wet seed which quickly rots. Most bamboo seed is collected from the ground. To simplify this the ground should be cleared of litter and vegetation, or sheets placed under the flowering branches when seed fall is first observed, and the seed should be collected daily. Knocking the culms helps to remove the seed. Seed which lies on the ground for any time can be destroyed by insects, rodents or fire. If the amount of seed which is produced is very small, cultivation and protection of the land under the clumps allows the development of natural regeneration which can be transplanted via plastic bags into nurseries, given sufficient care. This may be easier than collecting and sorting very large amounts of flowers containing few seeds.

After collection the seed should be cleaned, treated with insecticide, sun-dried and stored in sealed containers. Cleaning removes the seed from the flowers so that when the seed is transplanted and stored there is less bulk and there are no insects outside the seed. After rubbing the flowers so that the seed falls out it can easily be sorted by winnowing on a *nanglo* (bamboo tray). Treatment with insecticide is necessary for *D. hamiltonii*, and probably other species as well. A small narrow brown moth, *Sitotroga cerealella*, lays eggs on the seed. The larvae burrow into the seed where they grow and eat the contents before emerging, leaving a round hole with distinctive white papery remnants of the cocoon visible. These moths have a short life cycle of five weeks in warmer areas and can destroy 60 per cent of the seed within six months. Drying in the sun for one day should reduce the moisture content satisfactorily. Indian experience with *D. strictus* suggested that eight per cent moisture content was best for storage (B.N. Gupta and Sood, 1978). Drying in the sun for several days could reduce the moisture content below this and damage the seed. If the moisture content is much higher the seed will rapidly deteriorate.

Germination of seed of *D. hamiltonii* collected in January and stored in cloth bags after sun drying fell from 92 to 75 per cent before the monsoon and to seven per cent after the monsoon in November. Dried seed stored in a sealed container with silica gel and dried seed stored in a refrigerator without silica gel gave 25 and 22 per cent germination respectively in April, after 62 weeks. Thus with proper storage the seed can still be of some use the following season, while without proper storage it is only viable for one season, losing its viability in the monsoon. Dormancy in bamboo seed is not known (McClure, 1966).

Raising seedlings

Bamboo seedlings are more susceptible to water stress than many other seedlings. They require ample regular watering and good shading to protect them from direct sunlight. They grow best in nurseries in cooler, damper areas rather than those on low exposed south-facing slopes. As *Dendrocalamus*, *Bambusa* and *Drepanostachyum* species are not generally frost-hardy they should be raised below the frost line. The optimum temperature for germination of *D. hamiltonii* seed is most probably higher than that for many temperate forest tree species and sowing should be delayed until the weather is quite warm. As germination may be expected to be low, and transplanting seedlings is not reliable in any but the best conditions, seed should be sown directly into polypots. Two to five seeds should be put into each pot depending upon the age and quality of the seed, and large polypots 4 inch x 7 inch (10 cm x 18 cm) or 5 inch x 8 inch (12.5 cm x 20 cm) lay-flat should be used. Germination of fresh seed of *D. hamiltonii* is very prompt (2–7 days), but seed stored for a year takes 6–8 weeks. M.W. Campbell (1983a) recommended a pre-treatment of two days

in water. The seed should be sown in April in nurseries below 1600 m, in May at higher altitudes. After the seed is sown a layer of mulch should be put over the soil in the polypot, and the seedlings allowed to grow up though this, under shade. Seedlings should not be exposed to direct sunlight. In the Terai seedlings will need at least 15 months in the nursery; at higher altitudes 27 or 39 months. For planting out, seedlings should be at least 150–200 cm in total height with three or more culms.

It is possible to increase nursery stock by dividing seedlings in the nursery. M.W. Campbell (1983a) recommended raising seedlings in beds for annual division. Seedlings in beds may not grow as fast as those in containers, however, although division is easier. Division of seedlings is only suitable after they have at least four healthy shoots. It is especially feasible in *Drepanostachyum* species (nigalos) which produce more shoots of smaller stature than *Bambusa* and *Dendrocalamus* species. Dividing the entire cylinder of root and soil from a container-raised plant with a razor blade so that each half has a strong young shoot, and replacing these in polypots with some fresh soil has been successful in a hot, dry nursery as well as a cooler one in all three genera. In the hotter nursery, however, growth rates have been higher and the plants have also had to be divided in the growing season, which is only possible by covering each divided plant with a sealed polythene tube, under very good shading, for two weeks. This technique also had to be used for transplanting seedlings in the hot, dry nursery in the growing season. Thus it seems that division of seedlings is only suited to cooler or more humid nursery locations.

Planting and management

Whatever technique is used for planting bamboos there is likely to be a shortage of planting material, so the bamboos should be planted at the desired final spacing, at least 5 m x 5 m. On difficult sites it may be necessary to use a nurse crop or to introduce bamboo by underplanting. The trees should be thinned out to allow the bamboo enough light when *Dendrocalamus* and *Bambusa* species are planted. *Drepanostachyum* species are shade-tolerant but would be more productive under a relatively light canopy.

Harvesting of bamboos is ideally an annual operation. *Bambusa* and *Dendrocalamus* culms which are grown for structural uses should be cut in their second or preferably third year leaving the younger culms to grown on. To season them they can be severed at the base and left in the clump until dry, then extracted and trimmed later. *Drepanostachyum* culms for weaving are cut after 16–20 months. All culms removed are steeped in water to remove starch and make them more flexible, either before or after splitting into strips. The remaining culms are tied together to prevent them collapsing after the support of the older

culms is removed. Use of fertilizers is a common practice with bamboos, which respond well. Household refuse, such as old thatching, and manure are often applied. Rhizomes are susceptible to drying out if they are not covered so the clump should have earth piled into it to counteract soil erosion and encourage good rhizome development. If a stand of bamboo flowers and dies, the area should be protected against grazing animals and fire until it has re-established itself from seedlings.

Pests and diseases

The most serious pests of bamboos in Nepal are the larvae of shoot-boring moths of the family Noctuidae. The commonest species in the eastern hills is a *Pareuplexia* species (Stapleton, 1985b). The brown eggs are laid on new culms in the monsoon and the small larvae eat their way into the culm cavity through a hole in the softest region of the internode towards the base. Once inside they eat extensively into the walls of the culm, progressing upwards to where the tissues are softest, leaving a small circular hole in each nodal diaphragm and long grooves on the walls which may show through to the outside as streaks or slits. In severe cases the top of the culm dies and may fall off. The white larvae with brown head capsules can reach 5 cm in length and more than one hundred have been found in a single culm.

In *Dendrocalamus* species the larvae usually return to overwinter in the internode which they originally entered, sealing the hole in the diaphragm above to keep dry, and pupate about two to four weeks before emerging through the original entrance hole as adult brown large-bodied moths. They may also occasionally overwinter in the dead top of an infected shoot between the culm sheaths. In *Bambusa* species a gelatinous substance is produced in the internodes when they are damaged. This kills many larvae and usually prevents overwintering inside the culms in these species, though a few larvae can overwinter higher up.

The incidence of shoot borers is related to management. Where this is intensive and culms are regularly cut incidence is relatively low. It would be very high in a plantation during establishment and special sanitary measures would be necessary. In *Dendrocalamus hookerii* in one village around 10 per cent of new shoots were infested on average; increasing to 25–30 per cent in totally neglected clumps. Cutting out infested culms during the winter and removing dead culm tops would quickly control this insect. Simpler measures such as blocking the entrance hole (which is usually at a convenient height 0.5–2 m above the ground) may be effective in reducing numbers appreciably. As most moths emerge from *Dendrocalamus* species attention to these alone may be sufficient.

Other species of moth attack small bamboos, but the incidence appears to be much lower. One *Drepanostachyum* species produces a thick gelatinous coat on the outside of new shoots, which may be an adaptation to protect against attack by shoot borers. Being nocturnal, noctuid moths are seldom seen around the clumps, and it is a popular misconception that the damage is caused by a different insect which is more conspicuous. Another popular misconception is that shoot borers are encouraged by cutting culms on Sundays and Tuesdays. A bamboo blight observed in Bangladesh has not been seen in Nepal.

Uses

Bamboos have very many uses and it is impossible to enumerate them all in a short space. In all except the driest and highest regions of the country bamboo products are an integral part of rural life and it is extremely difficult to imagine the rural economy without them. The culms can be used entire, split into sections, crushed into panels, or split and then woven. The culms of *Bambusa* and *Dendrocalamus* species are used entire for strong rafters, pillars and fence posts. After splitting they are used for roof lattices, floors, ceilings and walls. Some *Dendrocalamus* species (especially *D. hamiltonii*) are used for weaving. *Bambusa* species and other *Dendrocalamus* species are less flexible and so not as good for this purpose. Culms of *Drepanostachyum* and *Arundinaria* species are more important for weaving as the outer layers produce more flexible and durable material than can be obtained from *Dendrocalamus* or *Bambusa* species. Woven products include baskets, mats and trays used for collecting, sorting, transporting and storing agricultural products. Baskets are the principal medium of transportation for most goods beyond the road-heads in the hills. Culm sections are now finding a modern use reinforcing concrete, especially in small works such as water tanks and toilet slabs.

Bamboo leaves are well known to be very nutritious and palatable as animal fodder. Negi (1977) and Negi *et al.* (1979) have shown the chemical composition and taste of some *Bambusa* and *Dendrocalamus* species to be among the best available from fodder trees. In contrast to all other fodder species examined Wood *et al.* (1992) found that the leaves of a bamboo contained no tannin, a substance which is sometimes harmful to animals. *Dendrocalamus hamiltonii* in particular has been highlighted as one of the most important sources of fodder in neighbouring Himachal Pradesh. In Nepal the larger bamboos are particularly important as a fodder source in parts of the southern Terai, where few forests survive as fodder sources. Branches and waste culm material are readily used as fuelwood. In areas with a great deal of bamboo it can constitute as much as 50 per cent of fuelwood used, although it is far from ideal for this purpose.

Young shoots of several species are commonly used as a vegetable, although this use is not as extensive in Nepal as in other Asian countries. In Ilam and Taplejung Districts, *D. hamiltonii* is the main source of edible shoots, but is only used by households who have surplus of this bamboo; others presumably prefer to allow the culms to develop for other uses (Blake, 1987a). Paper is made from bamboos in many countries; they are the principle source of pulp in India and Bangladesh. In addition to the more mundane uses of bamboos they are also used on many festive or religious occasions. They support symbols of the deities and prayer flags on mountain passes and summits and around houses. They are used to make swings, especially during the Dasain festival. At weddings four small poles may be placed as a guard around the centre of activities and the bride may be carried in a bamboo sedan chair or cage. Corpses are carried to cremation on a single pole of certain species.

From the point of view of utilization the important bamboos can be broadly divided into four categories: large construction species; large multipurpose species; small low-quality weaving species which can easily be cultivated; and small high-quality weaving species which cannot be cultivated outside the temperate forests. The first category is typified by *Bambusa nutans*. The culm walls are thick and strong, but inflexible and brittle so of less use for weaving. Poles are used for carrying the dead and shoots are never eaten. The second category is typified by *Dendrocalamus hamiltonii*. The culm walls are thin and flexible and good for weaving, but not strong or rigid enough for many constructional purposes. The large leaves however make good fodder and the new shoots are very palatable for human consumption. Both first and second categories are called types of bans in Nepali. The third category is typified by *Drepanostachyum intermedium*. The small culms have no constructional value, but are superior to those of the larger genera for weaving. While they are not the highest quality bamboos they can readily be cultivated at altitudes down to about 1200 m and represent a good compromise between quality and availability. The shoots are not palatable. They are known as types of nigalo. The fourth category includes several other more exacting *Drepanostachyum* species and *Arundinaria maling*. They produce the highest quality weaving material and also palatable shoots. The *Drepanostachyum* species are commonly known as malingo or more properly malinge nigalo while *A. maling* is always known as malingo.

In the Middle Hills people often have access to all four categories. The first three are planted on their own land and the fourth is collected from the forest periodically to supplement their own supply of weaving material. In the higher hills and some western areas the first two categories will not grow and thus bamboo has little constructional function. In the lower hills and Terai the last

two categories will not grow so that weaving is of a much lower standard and not so important. Table 23 (from Stapleton, 1982) summarizes the qualities of *Bambusa* and *Dendrocalamus* species needed for different purposes in eastern Nepal. Seeland (1980) gave a comprehensive list of uses in a Rai village there.

Table 23—List of principal uses of bamboos (In order of diameter)

Use	Desirable dimensions and qualities
Container	Diameter of cavity more than 12 cm
Pillar for shelter or drying rack	Outside diameter more than 15 cm, wall more than 3 cm
Roof beam or truss	Diameter 10–15 cm, wall more than 2 cm, straightness
Thatch supporting lattice	Wall less than 3 cm, diameter 7–15 cm, straightness
Fence post	Diameter more than 10 cm, durability
Fencing rail (split)	Wall less than 2 cm, splitting ability
Flooring/ceiling (split)	As for thatch lattice
Wall panelling (split)	As for thatch lattice
Split and woven mats and panelling	Wall thickness 1–2.5 cm, straightness, minimum nodal swelling, long internodes
Split and woven baskets and trays	Wall 1–2.5 cm, flexibility, minimal nodal swelling, straightness, long internodes.
Crushed and woven panelling	Wall less than 1 cm, flexibility
Split bands for tying (choya)	Flexibility, strength, splitting ability.
Fodder	Heavy branching
Fuelwood	Bent, thin-walled, no other use

Important species

In the first edition of this manual, 11 species of large bamboo (bans) and nine species of smaller ones were described, with Nepali names, and Latin names where these could be assigned reliably. Type numbers were also assigned, as these can remain consistent while both Latin and local names vary. The type numbers are included with the descriptions; [K] indicates that the names have been verified at Kew.

Since the first edition was published, a number of additional species of bamboos have been recorded from Nepal. As is always the case with bamboos, positive identification by Latin names has been very difficult, and even Nepali names vary; the tama bans of Ilam is not always the same as the tama bans of the Kathmandu Valley. Additions to the list since 1987 have been indicated by an asterisk. Because the taxonomy of bamboo species and genera is at present being revised worldwide some of the names given are likely to be altered in the future, especially the generic names. There is also likely to be controversy for some while as to which name is correct and different authors may use different names, hence the great importance of specific names and local names. Illustrations of most of the eastern species with further details for identification can be found in Stapleton (1982). A key to the genera found in Nepal based on the species known so far is given.

Vegetative key to principal Nepalese genera

- (1) Culms with grooves above the nodes *Phyllostachys*
- (1) Culms not grooved above the nodes 2
- (2) Culms attain a maximum dbh of less than 3.5 cm 5
- (3) Clumps very open, culms 60–90 cm apart *Melocanna*
- (3) Clumps denser 4
- (4) Culm walls thick and strong, branching usually fairly uniform from upper mid-culm to base *Bambusa*
- (4) Culm walls thin, basal branches usually much smaller than mid-culm branches or absent *Dendrocalamus*
- (5) Leaves with clearly visible transverse veinlets in addition to the longitudinal veinlets giving a chequered appearance when held up to the light 6
- (5) Leaves without visible transverse veinlets or with visible veinlets which are much more obscure than the longitudinal veinlets, culms arising in clumps *Drepanostachyum*
- (6) Culms arising singly from long slender running rhizomes which have elongated internodes *Arundinaria*
- (6) Culms arising in clumps from short rhizomes which are thicker than the culms and have short internodes; dead sheaths very persistent *Thamnocalamus*

Group I: Bambuseae Benth. and Dendrocalamae Benth.

Large stature bamboos (bans)

Bambusa and *Dendrocalamus* species

Holttum (1956) and Grosser and Liese (1973) consider that these two groups should be merged as the original distinctions made by Munro and Benthham conflict with vegetative and floral similarities, and are artificial. However by interpreting the original distinction loosely and adapting new criteria such as proposed by McClure (1966) and Lin (1972) we can maintain a very useful natural division into two genera with fairly clearly defined differences in uses, floral and vegetative morphology, propagation and susceptibility to insect attack in Nepal. *Bambusa* species generally have thicker walls, more uniform branching extending to the base, less aerial rooting, larger culm sheath auricles, less culm pubescence and glossy culms, smaller leaves, and longer flower clusters which appear spiky rather than orbicular, relative to *Dendrocalamus* species.

Bambusa nutans Wall. Mal bans. Type B1 [K].

The principal large-stature bamboo in east Nepal. It is very resistant to drought but not to frost, and occurs from the Terai up to 1800 m. It is used for all constructional purposes: its long straight internodes, no nodal swelling and relatively light branching, make it highly prized. It is however inflexible so is not good for weaving. Culm sheath hairs black, culms always round, well spaced. Sporadic flowering very infrequent and seed rare, though a small quantity was collected in the Dhankuta area in 1987. Not known to have flowered gregariously in living memory. Propagation by culm cuttings is difficult as there are no aerial roots, and rooting percentage is low, usually only about 10 per cent; thus propagation by culm offsets is the only reliable method.

Bambusa sp. Tharu bans, sate bans. Type B2.

The central Nepal equivalent of *B. nutans*, very similar in all respects and difficult to distinguish though it has dark brown culm sheath hairs, a groove on small culms, and shorter rhizomes making the clumps more congested. The flowers are completely different. Sporadic flowering has been noted in several localities over the past years, notably in the Kathmandu Valley. It also flowered in Kaski and Palpa Districts in 1986. However no fertile seed has been produced. It has been successfully propagated by single node cuttings, with 75 per cent success achieved with careful planting in a cool nursery. This species is a

little inferior in form to *B. nutans*. It occurs at least as far west as Kaski District, where it is known as sate bans.

***Bambusa balcooa* Roxb. Dhanu bans, bhalu bans. Type D23 [K].**

A central species less common than the previous one, met more frequently toward the west. Stature if not harvested intensively becomes much larger than that of the previous two species, up to 16 cm dbh compared to 12 cm. This species combines features of both genera, *Bambusa* and *Dendrocalamus*. Culm walls are thick and strong, branching is dense and slightly thorny low down, both *Bambusa* features. Culms are covered in brown pubescence at first though glossy later, culm sheath auricles are completely absent, mid-culm central branches are large and aerial rooting is well developed, all *Dendrocalamus* features. In the absence of culm sheaths the leaf sheaths, which are brown pubescent at first, distinguish it from the previous species, which have glabrous leaf sheaths. Sporadic flowering has been observed in Kathmandu for several years but no seed has been produced. This species is fairly easy to propagate by culm cuttings. Because of its large stature which makes it unsuitable for village use, and the congested thorny nature of the clumps which make it difficult to manage, it is not recommended for general use though it might be suitable for some special uses such as scaffolding for large buildings. It is also known as harouthi and bolka bans.

***Bambusa arundinacea* Wild. Kante bans.**

Planted because of seed availability in India this large bamboo is extremely thorny, producing interlacing thorny branches that make the culms difficult to extract (Troup, 1921). It may occur naturally in far western Nepal up to 1250 m.

***Bambusa vulgaris* Schrad.**

Planted for the ornamental value of its yellow striped culms, this species is smaller in stature than all the Nepalese *Bambusa* species, with shorter internodes, raised nodes, heavy branching and sometimes crooked culms. It is inferior to the Nepalese species but because of its ease of vegetative propagation it has been widely planted in many countries, mainly for pulp rather than the more sophisticated Nepalese end uses. It is not reported to flower.

****Bambusa glaucescens* (Willd.) Holttum. Pahelo bans.**

Found in the Kathmandu Valley in moist areas between 1000 and 1500 m. Culms bright yellow with green stripes, very similar to some varieties of *B. vulgaris*. Culm sheaths of new shoots purplish red. Ornamental only. Nepal specimens belong to var. *striata* (Poudyal and McCracken, 1992).

****Bambusa* sp. Mokla bans.**

Common in the Terai in eastern Nepal, also in central Nepal. Used for construction and woven products such as mats (Das, 1988).

***Dendrocalamus hamiltonii* Nees & Arn. ex Munro. Tama bans, ban bans, choya bans. Type D4 [K].**

Common in eastern, central and western Nepal from 300 to 2000 m. It is probably the most widely distributed Nepalese species, being an eastern equivalent of the widely distributed Indian species *D. strictus*. It is better adapted to the wetter and higher regions to the east and north of the natural range of *D. strictus*. It is recognized by its dense and persistent white and brown culm pubescence, naked triangular culm sheath auricles, and narrow dentate culm sheath ligule.

It is the ultimate multipurpose species, being large enough for constructional purposes, flexible enough for low-grade weaving, with large leaves for fodder and palatable shoots for human consumption. It is not as strong as *Bambusa* species, however. It is reported to flower gregariously and sporadically and provides seed in many areas; there are about 40,000 seeds kg⁻¹. It also responds well as culm cuttings, with more than 70 per cent of the nodes rooting even under arduous conditions.

According to Blake (1987a) the choya bans of Taplejung seems to differ from that of Ilam. It has smooth glossy culms 8–10 cm in diameter, and smoothly tapering, almost glabrous, culm sheaths which lack auricles and cilia.

***Dendrocalamus* sp. Phusre bans, khosre bans, tama bans. Type D13.**

This species is also very widespread in the hills between 1500 and 2000 m, though it is less frequent in the western region. In the east it is distinguished from the previous species because it is not so flexible and not good for weaving. In the central region the two species are not distinguished and both are known as tama bans. While similar in appearance to *Dendrocalamus hamiltonii* it can

be separated by the culm sheath auricles which are small and ciliate. The culms are straighter with less nodal swelling and the sheaths are very closely pressed to the culms. Culm sheath hairs are a light brown rather than dark brown colour, and the ligule is wide and serrate.

While this is an acceptable species for weaving in central Nepal, it is not suitable for the higher standard weaving in the east, and is used as a general purpose species. It flowers sporadically. No seed has been collected, but ample regeneration has been transplanted. Culm cuttings have been very successful. This appears to be the tama bans of Kathmandu Valley, *Dendrocalamus* sp., of Poudyal and McCracken (1992).

***Dendrocalamus hookerii* Munro. Kalo bans, bhalu bans. Type D1 [K].**

Common in the eastern hills from 1500 to 2000 m. It is the most cold-resistant Nepalese *Bambusa* or *Dendrocalamus* species. It is also reported from the far west. It is very similar to *B. balcooa* but has thin walls, no low branches, and culm sheath auricles with long bristles. The dense brown pubescence on culms and culm sheaths gives it the name *bhalu* (bear) which it shares with *B. balcooa*. When not harvested intensively this species attains larger stature than the other *Dendrocalamus* species, reaching 18 cm dbh, but is commonly managed to produce smaller poles, which are not so vigorous and hairy, and are usually called kalo bans. Sporadic flowering has only rarely been seen and no seed or seedlings have been produced. Culm cuttings gave nearly 85 per success under arduous nursery conditions. Also called kalo tama bans (Poudyal and McCracken, 1992).

***Dendrocalamus* sp. Dhungre bans. Type D6.**

Locally common in the hills of eastern Nepal and more common in the central region between 1500 and 2000 m. As with type D13 it is difficult to separate from *D. hamiltonii*, and the name is not satisfactory as it is used for many other species when they attain large stature and can be used as a *dhungro* (cylindrical container). *Dhungro* were the principal water containers before clay and metal pots were introduced and they are still used in poorer areas. Apart from containers this stocky species provides pillars for small buildings and is especially used for fodder. The large branches can be used for weaving material, although the culms are unsuitable.

It has corrugated culm sheath blades and short wide internodes which are often swollen and give the culm a zigzag appearance. Sporadic flowering is infrequent. As only very old flowers have been found it is not known whether

this is really a separate species or just a variety of *D. hamiltonii*. As it produces strong aerial rooting it should be very successful when propagated by culm cuttings, but it is similar to *D. hamiltonii* which is much easier to propagate, producing ample seed.

See also *Dendrocalamus giganteus*.

***Dendrocalamus patellaris* Gamble. Nibha bans, lyas bans.**

Type T3 [K].

The smallest of the *Dendrocalamus* species. It attains a maximum dbh of around 4 cm and is almost semi-scandent, the apex sometimes nearly reaching the ground or resting on tree branches. The internodes are long and ribbed, the nodes have a wide frilly collar, and the culm sheaths have very long-fringed edges. It is frequent in Mechi zone and occasional in Koshi zone between 1950 and 2600 m, where it is known as nibha, and has also occasionally been seen in western Nepal in the high rainfall area around Pokhara, and in Palpa District where it is known as lyas bans (Schaltenbrand, 1982). It produces good quality weaving material but is too small for constructional purposes. It is also used for making flutes and hence it is sometimes called murali bans. Gregarious flowering occurred in the east between 1980 and 1982 and some seedling regeneration had attained almost full stature by 1984 in Pakhribas. Cultivation outside its area of natural occurrence is not considered likely to be successful except as an understorey crop. Also known as gopi bans (Das, 1988).

***Dendrocalamus strictus* Nees. Kath bans, lathi bans.**

This species has been widely planted especially by farmers in the Terai, because of seed availability from India; it may also occur naturally in far western Nepal up to 1000 m. It is a small species reaching only 7 cm in diameter (Gamble, 1896). It is limited to low areas below 1000 m, and according to Troup (1921) is not found in moist localities. He considered it to be the hardiest of all Indian bamboos, being found in low areas prone to excessive drought and frost. Deogun (1937) described it as flourishing in areas where the humidity is low, beyond the influence of sea breezes, and stated that it could stand a mean average rainfall of 750 mm and minimum temperature of -6°C. He also stated that it does not grow on waterlogged or heavy soils, preferring a sandy loam overlying boulders. Thus it would appear to be most suitable for the Siwaliks and non-alluvial Terai deposits in the Mid-Western or Far Western Development Regions of Nepal. It has been planted elsewhere, however, especially around Tansen, Palpa District. The culms are almost solid, used for rafters and posts, and for walking sticks. It is a good fuel and makes excellent

charcoal. The leaves are prized for fodder, especially for buffaloes and horses (Poudyal and McCracken, 1992).

****Dendrocalamus giganteus* Munro. Bhalu bans.**

This species grows up to 1500 m. It has very large culms, up to 25, sometimes 30 cm, in diameter. The culm sheaths are up to 50 cm long, and are shiny with golden hairs. The culms are used for buckets and water containers, and for posts, but not for rafters. Hollowed out culms are used as irrigation channels. Nodal cuttings gave 60 per cent success in unshaded beds, and it is considered that with shade even better results could be obtained (Poudyal and McCracken, 1992).

****Bambusa* or *Oxytenathera* sp. Koraincho bans.**

Found in the inner Terai and the Siwalik Hills in central Nepal, in natural forest and planted on farmers' lands. Culms solid, yellow striped; branches strong. Used for construction and weaving. Culm cuttings gave only 20 per cent survival (Das, 1988).

****Cephalostachyum capitatum* Munro. Gopi bans.**

Given by Poudyal and McCracken (1992) as an alternative identification of gopi bans, *Dendrocalamus patellaris*. The two species are distinct, though they superficially resemble each other. *Dendrocalamus patellaris* has green stems, *C. capitatum* yellow. Uses similar.

Group II: Arundinariae Steud.

Small-stature bamboos (not bans)

Types of nigalo or ningalo and others e.g. malingo

***Drepanostachyum*, *Arundinaria* and *Thamnocalamus* species**

All small-stature bamboos were once put into the genus *Arundinaria* which became unwieldy, with 482 species at one time. Many botanists have divided the genus progressively and Nepalese species have repeatedly been put incorrectly into different genera without proper inspection. There has been much controversy, which will undoubtedly continue. Twelve new genera have been described by Chinese researchers in the past five years. Three distinct groups of small-stature woody bamboos are commonly found in Nepal, and these can now be assigned to genera, which are distinguished on the natural grounds of

morphology, ecology, uses and local names. However, as the diversity of small bamboos is great and their range, from 1200 to 4000 m, covers so much difficult terrain it will be a very long time before all the species are properly known, and other genera may come to light.

By far the most important group of species usually occurs below areas of severe frost. They are mostly known as kinds of nigalo. They all grow in clumps and none has the pronounced chequered-leaf venation known as tessellation found in truly frost-hardy genera at higher altitudes. While some are resilient and are commonly cultivated in the open down to about 1200 m, others will only grow well above 2000 m, preferably under a forest canopy.

Despite the great importance and prevalence of this group in Nepal none of the many generic names produced in subdividing *Arundinaria* had been applicable to them until 1983 when Keng in China published a name for them—*Drepanostachyum*. Most earlier names applied to non-clump forming groups of species. All *Drepanostachyum* species can be used for weaving, though some are superior to others, and one is not used at all for that purpose as it is very sharp and cuts the hands. Some produce edible shoots while others are bitter (tite). Two species are very abundant, commonly cultivated and of great importance.

***Drepanostachyum intermedium* (Munro) Keng. Tite nigalo.
Type T1 [K].**

The common small-stature bamboo in eastern Nepal, found from 1200 to 2400 m, both in cultivated land and occurring naturally in forest areas, usually from 1200 to 1800 m, attaining progressively larger stature with decreasing altitude. This is a resilient species often encountered on hot, dry exposed banks or between rocks, where no other small stature bamboo except the following species could survive. Its leaves are often curled up completely to reduce water loss, but it appears to thrive on such sites. It is used mainly for weaving into baskets and mats. Its leaves are good as fodder and fed to goats and sheep while the culms are being woven in winter. Its importance lies in supplying quantities of reasonable quality readily available weaving material for harvesting, sorting, transporting and storing agricultural produce, especially where there is limited access to the forest bamboos found at higher elevations, which is increasingly the case throughout the country. It is reported to frequently flower sporadically (Gamble, 1896), and this has been observed. Small quantities of seed have been obtained, and dense regeneration has been transplanted into the nursery for several years. Recognition of this species is by its long spreading setae on the

auricles of its hairy leaf sheaths and the long ragged ligule on its culm sheaths, which are rough inside towards the top, and glabrous outside.

***Drepanostachyum khasianum* (Munro) Keng. Tite nigalo.**

Type T21.

A direct equivalent of *D. intermedium* which it replaces in central and western Nepal. It is distinguished from *D. intermedium* by the eventual lack of setae or auricles on the glabrous leaf sheaths, and the ring of dense brown hairs at the base of the culm sheath. It has not been found in flower and the identification is speculative as this species has few distinctive vegetative features.

Note: Several other *Drepanostachyum* species have been found, but their occurrence has generally been local. They all require a cooler and damper environment and care should be taken to plant them in sites where they can be successful. A few are important enough to deserve mention.

***Drepanostachyum hookerianum* (Munro) Keng. Padang.**

Type T4.

A distinctive eastern species with blue culms which is cultivated above 2000 m, and attains a larger stature than the previous two species, up to 3 cm dbh. It is considered no better than the previous species for weaving although the larger size makes it easier to use. The culm sheath is distinctive, narrowing concavely almost from the base, while others narrow from at least halfway up the sheath. It has not been seen in flower. According to Blake (1987a) people in Taplejung bring cuttings down from higher altitudes to plant near their houses.

***Drepanostachyum* sp. Malinge nigalo. Type T3/2B.**

A less well-known eastern species which is also cultivated outside the forest, though on a smaller scale. The short internodes (15 cm maximum) distinguish this from the other cultivated eastern species which all have longer internodes, up to 25 cm. It has no auricles or setae on the leaf sheaths and short ligules on the culm sheaths which attenuate convexly, not concavely as in all the previous species. Flowers have not been seen. This species apparently produces better material for weaving than all the previous species, and has been found cultivated at 1800 m in the open.

***Drepanostachyum* sp. Malinge nigalo. Type T29.**

This central species occurs from 1800 to 2800 m along the Langtang Khola, but how far it is distributed into other areas is not known. It has not been observed in cultivation, only in natural forest stands. It is quite similar to the previous species but has long erect setae on the culm sheath shoulders, and small auricles with long erect setae on the leaf sheaths. One sporadically flowering clump has been seen. It also yields weaving material of superior quality from longer internodes.

***Drepanostachyum* sp. Malinge nigalo. Type T24.**

This western species is similar to the previous two, and is remarkable for its long internodes, up to 40 cm in length, and its large diameter, up to 3 cm dbh. It is very highly valued and managed intensively at 2500–3000 m in the forests around Pokhara for weaving material and also for its edible shoots. It appears to be more exacting in its site requirements than the previous two species which are found at lower altitudes, and differs by having copper-coloured cilia on the edges of the culm sheaths and a very short, broad ligule. While the leaves are not clearly tessellate the transverse veinlets are just visible.

Above the range of *Drepanostachyum* species, bamboos are smaller in stature and have tessellate leaves. By holding a leaf up to the light a chequered pattern is clearly seen, contrasting with the parallel venation seen in non-tessellate groups. This could be a physiological adaptation allowing quick transport of fluids in and out of leaf cells to allow frost-hardiness. The high altitude bamboos are clearly separated into two genera, according to whether they normally have short rhizomes (pachymorph) and form clumps or have long rhizomes (leptomorph) and produce solitary culms arising a substantial distance apart. Only the spreading (leptomorph) species can be put into *Arundinaria*, as it is understood here. The pachymorph species are included in *Thamnocalamus* (see below).

In 1973, McClure and Holttum recognized *Arundinaria* species from Nepal (probably *A. maling* and *A. racemosa*), and the opinion of two of the most eminent bamboo taxonomists cannot lightly be disregarded. Nevertheless some Chinese taxonomists have decided that *Arundinaria* is a monotypic American species, and *A. maling* certainly seems to have rather different branching to the American type species. For the time being, however, the two species of bamboo mentioned can be considered *Arundinaria* species. Leptomorph bamboos have different requirements to pachymorph bamboos. Shoot growth is typically in the spring, rather than the summer or autumn. Consequently they are more

abundant in areas with a more uniform pattern of annual rainfall and in Nepal have only been found in eastern Nepal at higher elevations. They are not yet known from central to western Nepal, nor from lower elevations in the east, but they may well reappear in high winter-rainfall areas of the Mid-Western and Far Western Development Regions of Nepal. One species is very well known and one not yet seen.

***Arundinaria maling* Gamble. Malingo. Type T9.**

The common high altitude eastern species, which can occasionally be found as low as 2300 m but becomes widespread above 2800 m. It is recognized by the very rough internodes on younger culms which feel like sandpaper towards the top. It is apparently the most highly valued bamboo for basket work in Nepal, producing very durable material indeed. It has not been found in flower. Propagation by offset cuttings in leptomorph bamboos requires the excavation of a greater length of rhizome than in pachymorph bamboos to include sufficient rhizome buds and roots and should be undertaken much earlier in the year. Very little is known of propagation by culm cuttings in leptomorph bamboos.

***Arundinaria racemosa* Munro.**

Blatter (1929) reports this to be found above the previous species in eastern Nepal, and to be distinguished from it by its smooth internodes. The two species are closely related and often confused with each other.

***Thamnocalamus* and other species**

The clump-forming tessellate species can be put into *Thamnocalamus*, a genus created for the Himalayan species by Munro (1868) rejected by Gamble (1896), re-established by Camus (1913) rejected again by Blatter (1929) and now recognized again by McClure (1966) and Yi (1983) for very good reasons. These species of central and western Nepal, are of little value as the culms are brittle and of no use for weaving. The leaves are used for fodder but are small. They make very good brushes as they are stiff and inflexible and as the branches are almost parallel to the culms.

Gamble (1896) gives two species in this group which may be found in Nepal, one, *T. aristatus* (Gamble) Camus, a Sikkim species which may well occur in Mechi zone, and the other, *T. spathiflorus* (Trin.) Munro, known as ringal which occurs under *Cedrus deodara* and fir forest above 2000 m from the Sutlej to Nepal, and so is likely to be found at least in the Far Western Development Region. These two species along with *T. falconeri* Hook. f. ex

Munro are included in the enumeration by Hara *et al.* (1978) of non-cultivated Nepalese plants.

Three other species of *Thamnocalamus* are known also, one from central Nepal (called ghore in Langtang) and two from western Nepal (called chigar and jarabutto). They have limited value although the western species are important food for the Nepalese national bird, the Impeyan pheasant, and for the Himalayan black bear. (See Stapleton and Tamrakar (1983b) which includes a key for identification of the small-stature bamboos in the Seti Khola valley north of Pokhara, Western Development Region.)

Semiarundinaria pantlingii (Gamble) Nakai, recorded in the Enumeration from eastern Nepal, also belongs here.

Two species of *Phyllostachys*, which also belong to the Arundinarieae, are described by Poudyal and McCracken (1992). *Phyllostachys* species can be distinguished by having internodes which are grooved on alternate sides above the nodes. *Phyllostachys nigra* (Loddiges) Munro, kalo nigalo, is cultivated for ornament in the Kathmandu Valley; the ripe culms are black, and about 3 cm in diameter. *Phyllostachys* sp., kata bans, with green culms 3-6 cm in diameter, is found in the hills of eastern and central Nepal above 1500 m; the culms are used for rafters. Young shoots of both species are good to eat. They can be propagated by rhizome cuttings.

Melocanna bambusoides (1992) Trin., of the Melocannae, is recorded by Poudyal and McCracken from the Terai and western hill districts up to 1500 m. According to Storey (1990) it was introduced from Assam. The necks of the rhizomes are elongated, so the culms grow 60 to 90 cm apart, in very open clumps; they are 4-7.5 cm in diameter, with very thin walls. The culm sheaths are about 15 cm long, covered with persistent whitish hairs, and with blades 30 cm long and 2.5 cm broad. The fruits are unlike the rice-like grains of other bamboos; they are large and fleshy, up to 12 cm by 7 cm. The flattened culms are used for house walls, and for weaving.

References: Papers published since 1987: Blake (1987a; 1987b); Bradshaw (1989); Das (1988); Howell *et al.* (1991); Napier and Robbins (1989); Poudyal and McCracken (1992); Storey (1990).

Bambusa see Bamboos.

Bassia butyracea see *Aesandra butyracea*.

Bauhinia L.

Caesalpiniaceae

Trees or large woody climbers. Leaves formed from two leaflets fused together. Flowers often showy, with five spreading petals and up to 10 long curved stamens. Fruit a pod.

Key to Nepalese species

- (1) Trees 2
- (1) Woody climbers 5
- (2) Cleft at apex of leaf deep, more than two fifths of total leaf length, and narrow; leaves usually slightly longer than broad; flowers about 5 cm long, petals bluish-white to rosy purple, upper one often with a yellow blotch; perfect stamens three *B. purpurea*
- (2) Cleft at apex of leaf shallower and broader; leaves usually as broad or broader than long; apex of lobes rounded 3
- (3) Cleft at apex of leaf very shallow, less than one fifth of leaf length, and sometimes absent; flowers less than 1 cm long, yellow with purple veins; ripe pods crimson *B. semla*
- (3) Cleft at apex of leaf deeper 4
- (4) Each lobe of leaf usually with three veins; leaves much broader than long; evergreen; flowers about 1 cm long, white or pinkish *B. malabarica*
- (4) Each lobe of leaf usually with four or five veins; leaves not or only slightly broader than long; deciduous in dry season; flowers 6–7 cm long, whitish to light purple, upper petal often with a deep purplish blotch *B. variegata*
- (5) Leaves large, over 18 cm long, hairy beneath; flowers white, fairly large, petals over 12 mm long *B. vahlii*
- (6) Leaves smaller, less than 11 cm long, without hairs; flowers yellowish-white, small, petals less than 3 mm long *B. scandens*

***Bauhinia purpurea* L.**

Nepali: tanki, rato koiralo.

(Sometimes called *B. longifolia* in reports.)

Natural occurrence

Found in all regions of Nepal, from the Terai to 1600 m; a common constituent of *Shorea robusta* and *Schima-Castanopsis* forest. Outside Nepal it ranges from Kashmir to southern China, and it has been widely planted for ornament in tropical countries.

Silvicultural characteristics

A moderate light-demander. In India it is reputed to be very frost-tolerant, though in nature it is found under an absolute minimum temperature of only -1°C (Troup, 1921). It is reputed to have some tolerance to poor dry sites, but on such sites its growth is often very slow. It does not have rhizobial nodules on the roots. The plants are liable to browsing damage: the greatest cause of mortality after planting.

Natural regeneration

The pods open on the trees during the hot season, scattering the seeds, which germinate soon after the rains begin. Usually numerous young seedlings can be found under seed-bearers, but unless the germinating seed becomes partly covered in soil, most seedlings will dry due to withering of the rootlet.

Artificial regeneration

Seed

The seed ripens between February and May, with a tendency to be later in the west than in the east. As the tree is used for fodder, and the young flower buds are eaten, it is necessary to buy or rent trees to secure a seed supply. The pods should be collected when they are brown, just before they open. The seed is extracted by drying the pods in the sun and allowing them to open. There are between 4000–5000 seeds kg^{-1} . They should be dried thoroughly and be stored in sealed polythene bags, when they will retain their viability for at least twelve months. No pre-treatment of the seed before sowing is necessary. However soaking in cold water for a day, changing the water three or four times during this period, may help to reduce fungal attack. Germination begins 5–10 days after sowing and is completed 1–2 weeks later; the germination percentage is usually good (85–95 per cent). In practice community forestry nurseries have raised from 600 to 1900 plants kg^{-1} of seed.

Nursery and plantation techniques

Seed should be sown directly into polypots at the rate of two seeds per pot. They should be covered with about 5 mm of soil. Deep sowing is harmful, as it reduces germination and causes distortion of the shoot. As the seedlings will usually be supplied to farmers for individual planting the use of larger polypots, 4 inch x 7 inch (10 cm x 18 cm) lay-flat is preferable, though the standard size can also be used. At lower altitudes growth in the nursery is rapid, and in the Terai and Bhabar Terai, up to about 1000 m, the seed should be sown in mid-May. Between 1000 and 1500 m sow in early March, and above 1500 m in August in the previous year, to allow the plants to be well developed by the onset of winter. If the plants are going to remain in the nursery over winter, a free draining potting mixture should be used, otherwise there is a danger of root rot. This causes leaves and shoots to die back, although new shoots may develop from the base of the stems in spring.

No shade is needed after the seedlings are about 2 cm tall. The plants soon develop long thin taproots, so frequent root pruning is necessary. Plants in standard polypots should be spaced out with 5–10 cm between the rows at the time of the first root pruning; this is not so essential if larger polypots are used, but is desirable. By the planting date the seedlings should be 20–30 cm tall, with root-collar diameters over 3mm, and well-lignified stems.

According to Troup (1921) stumps can be used, but the rate of growth is slowed down. So far little success has been achieved in raising plants from cuttings; buds and shoots have developed, but no roots have formed (Napier, 1988). Bare-root planting gave poor results at Pakhribas (P.R. Pradhan, 1982b).

Performance in plantations and rate of growth

In the first few years growth rates are rather slow, especially at higher altitudes. At Hetauda (470 m) 18-months-old trees were 1.7 m tall, on a site which had been weeded and thoroughly cultivated to a depth of about 20 cm, and also had been fertilized (Napier and Parajuli, 1987). At Pokhara (900 m) plants 34 months old averaged 1.6 m tall (van der Dool, 1987). Above about 1200 m in most places it appears that at least three years will be needed for plants to reach 1 m in height. Above 1600 m growth is very slow and plantation scarcely justified.

Uses

In Nepal its principal uses are for fodder, and for its buds and flowers which are cooked as a vegetable, though they are said to be inferior to those of *B. variegata* (Regmi, 1982). The crude protein content of its fodder is 12.6 per cent according to N.P. Shrestha and Pakhrin (1988), and 29.7 per cent accord-

ing to Panday (1982). Buffaloes in Pakhribas eating 8 kg fodder day⁻¹ in addition to grass and concentrates increased milk yields by 0.34 kg day⁻¹ (N.P. Shrestha and Pakhrin, 1988). The main season for utilization of fodder in most places is from November to February; the new leaves flush in late March to late May (Panday, 1982). However considerable use is made at other times of the year; in Dhading District, west of Kathmandu, a great deal is used in the monsoon (Upadhyay, 1991).

Studies of yields from lopping in Dhankuta District, at less than 1300 m, were made by Oli (1988). Lopping there begins when the trees are five years old, and the first yield, from one lopping, averages about 9 kg fresh weight per tree. Older trees are lopped twice yearly, first in February and March, and then in April and May from the new growth. The average yield from well-grown trees from the first lopping was 87 kg fresh weight (range 60–111 kg), and from the second lopping 38 kg (range 21–51 kg). The dry matter content from the first lopping was 50 per cent of the fresh weight, from the second lopping 17 per cent. Cattle ate branches up to 1.5 cm in diameter, and buffaloes ate branches up to 2 cm.

T.J. Wormald *et al.* (1983) estimated that trees 20, 30 and 50 cm in diameter would produce 19, 45 and 72 kg dry weight of fodder per tree respectively. The dry weight of leaves is 64 per cent of the green weight. These are at least of the same order of magnitude as Oli's figures. S.M. Amatya and Lindley (1992) measured 4 kg fresh weight from loppings of trees 4.3 years old at Adabhar. The wood weighs about 720 kg m⁻³, and is a good fuelwood. It is mainly used for agricultural implements.

Importance in Nepal

It is a very important source of fodder, but probably more from its abundance than from farmers' preference. Indeed in some areas, such as Lumle, it is among the most unpopular trees for planting by farmers. However elsewhere it is valued more highly. In Lalitpur District farmers have planted it quite widely, with survival rates ranging from 38 to 63 per cent; roughly similar results were obtained in farmers' plantings in the Nepal–Australia Community Forestry Project area. Its rather low growth rates at altitudes over 1500 m are not encouraging.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Rao and Purkayastha (1972); R.V. Singh (1982); Troup (1921).

***Bauhinia variegata* L.**

Nepali: koiralo, seto koiralo, kachnar.

Occurrence

Throughout Nepal, up to 1900 m. It has a somewhat higher altitudinal range than *B. purpurea* and it occurs frequently in pine-*Schima* forest, in addition to *Shorea robusta* forest. Outside Nepal it occurs in the Himalaya from the Indus to Bhutan, and extends to Burma and Thailand.

Silvicultural characteristics

It is a light-demander. The seedlings are frost-tender, but older plants can withstand heavy frosts, though they are defoliated. It is reputed to grow on dry rather infertile sites, but growth is better on porous, well-drained sites; it will not withstand waterlogging. It coppices well. Young seedlings are very susceptible to damage by browsing. It is vulnerable to fire.

Natural regeneration

Similar to *B. purpurea*, except the seeds tend to ripen rather later.

Artificial regeneration

Seed

The seed ripens between March and May, or June in the west, that is rather later than *B. purpurea*; there are 2500–3500 seed kg⁻¹. About 1000 plants kg⁻¹ have been raised in nurseries. Otherwise similar to *B. purpurea*.

Nursery and plantation techniques

It is slightly slower growing than *B. purpurea*, and below 1000 m will need about three and a half months in the nursery, i.e. it should be sown in April. The technique for raising polypot plants is otherwise the same as for *B. purpurea*. Planting *B. variegata* as stumps is also possible; the seed is sown in drills in the nursery, and the stumps made about 12 months later. Direct sowing in the field gave fairly good establishment in the Tinau area, but subsequent growth was very slow, only 10 cm after three rainy seasons (Schaltenbrand, 1982), so the method is not very practicable. Bare-root plants have given very poor results.

Performance in plantations and rate of growth

Its survival in trial plantations is usually good, and at altitudes over 1600 m appears to be better than that of *B. purpurea*. Growth however is rather slow, especially at altitudes of over 1500 m. In trials which were weeded, cultivated to 20 cm, and fertilized, after 18 months average height at Hetauda (470 m) was 1.7 m, and at Chalnakhel (1370 m) height was 1.6 m (Napier and Parajuli,

1987). In the Terai it reached 2.5 m at two years (M.B. Karki, 1988). Elsewhere 70–90 cm at 2.5 years would be fairly typical. Coppice regrowth in India averaged about 50 cm in height and 0.6 cm in diameter yr^{-1} (Troup, 1921).

Uses

It is valued in Nepal mainly as a fodder tree, and for human food. The buds and flowers are boiled, then curried and fried; protracted use, however, causes constipation (Regmi, 1982). As a fodder, in composition it is not quite as good as *B. purpurea*. It has about 19 per cent crude protein, with a digestibility of 25 per cent (Panday, 1976a; 1982). It has a low Ca:P ratio, and if eaten in large quantities causes milk yield to decrease. In Lalitpur District farmers distinguish two varieties, seto koiralo and kalo koiralo; the former is said to produce better fodder. The period of year in which the fodder is used varies. In Dhading District farmers said that they used it mostly from mid-April to mid-December (Upadhyay, 1991), whereas in Lalitpur District the peak period of use was in February (Upton, 1990). Annual dry leaf fodder yield was estimated by T.J. Wormald *et al.* (1983) at 7.5 kg for trees 20 cm in diameter, 21 kg for 30 cm in diameter, and 42 kg for trees 40 cm in diameter. The wood weighs about 700 kg m^{-3} , with an energy content of about 20,100 kJ kg^{-1} (Hawkins, 1982), and is a good fuel. It is also used for agricultural implements.

Importance in Nepal

It is important firstly for its flower buds, secondly as fodder. It had about 48 per cent survival in community forestry plantations (J.G. Campbell and Bhattarai, 1983b), but did not do well in fodder trials at Chautara. The reports of its tolerance to poor sites are contradictory, and more details of this are needed. It is a rather higher altitude tree than *B. purpurea* and may be better than that species for altitudes between 1500 and 1800 m. Its popularity among farmers varies in different districts. In Dolakha District very few would plant it, but in other places it is planted on a moderate scale. Its main advantages according to farmers are drought-resistance, fodder yield, and coppicing ability.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Koul *et al.* (1989); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Rao and Purkayastha (1972); R.V. Singh (1982); Troup (1921).

Bauhinia malabarica Roxb. occurs in the Terai and *B. semla* Wunderlin (*B. retusa* Buch.-Ham. ex Roxb.) between 1200 and 1400 m. Both species are planted to some extent in India (R.V. Singh, 1982; Troup, 1921). *B. vahlii* Wight and Arn. (Nepali: mulu, bhorla) is a large woody climber, widely distributed in Nepal below 1300 m. The large leaves are a good fodder and are

also used for plates. (For other uses see Gamble, 1922) *B. scandens* L. var. *horsfieldii* (Miq.) Ohashi (*B. anguina* Roxb.) is also a climber but is confined to eastern Nepal below 400 m.

***Betula* L.**

Betulaceae

Birch

Trees with papery bark. Leaves alternate, toothed. Flowers small, in catkins. Fruit winged.

Key to Nepalese species

(1) Lower elevations, 1200 to 3000 m. Bark greyish-brown to reddish. Leaves over 8 cm long. Female catkins 2–4 together, pendulous *B. alnoides*

(1) Higher elevations, over 2700 m. Bark white to brownish. Leaves less than 8 cm long. Female catkins erect, single *B. utilis*

***Betula alnoides* Buch.-Ham. ex D. Don**

(Syn. *B. cylindrostachya* Lindl. but see 'Provenances' below)

Nepali: saur, also paiyu, ban utis, bhojpatra.

Natural occurrence

It has a wide altitude range in Nepal, from 1200 to 3000 m, and hence grows in a number of different types of forest, from *Schima-Castanopsis* to *Quercus semecarpifolia*. Outside Nepal it extends from Kumaon in the west to Bhutan in the east, and is also found in Assam, south China and Thailand.

Silvicultural characteristics

It is a light-demanding species, but less so than *B. utilis*. It is often found growing gregariously on landslips and other sites where the soil has been newly exposed, thus resembling *Alnus nepalensis*. It prefers fairly moist situations, and often grows near streams. It is frost-resistant, but liable to be damaged by browsing, and is fire-tender.

Natural regeneration

The winged seeds are carried fairly long distances by the wind. Seedlings cannot establish themselves under forest shade, or on weed-covered ground.

Artificial regeneration

Seed

The date at which the seed ripens appears to vary a good deal, from October to February or March. The catkins are stripped off the trees as they begin to turn from green to yellow-brown. They are spread thinly on trays, and dried in the sun for several days until they turn fully yellow; they are then broken up by hand, and the seed sieved and winnowed to remove wings and chaff. The seed is very light, about 5 million seeds kg^{-1} . One kilogram of fruit yields about 60 g of seed. The seed is orthodox and should be dried thoroughly and stored in sealed plastic bags. If kept in unsealed containers or cloth bags it will lose its viability within a few months.

Nursery and plantation techniques

The seed should be sown at the rate of about 20 g m^{-2} in seed beds or seed trays, with the surface made level, and covered with a very thin layer of sand or sifted soil. The techniques for small-seeded species should be used. In Chalnakhel (1370 m), when seedlings were raised in sterilized sand in a propagator, seed sown in November began to germinate in mid-December and germination continued to mid-January. Subsequent growth of the seedlings was very slow, and it was not possible to prick them out into polypots until the latter part of April. The plants only began to grow vigorously in June. This slow growth may be due to low winter temperatures, and sowing after the end of the cold weather is preferable. Thus below 1800 m the seed should be sown in July, above 1800 m in March. In these conditions germination should begin 2–3 weeks after sowing, and be completed 2–3 weeks later.

Seed beds must be shaded and protected from heavy rain by covering the shades with plastic sheets. The shade should be continued until the seedlings are ready for pricking out. This should be done when the seedlings have two to three primary leaves, into 3 inch x 7 inch (7.5 cm x 18 cm) lay-flat polypots filled with a mixture of one part of sand to three parts of soil. This will be about two months after sowing. Shade and protection against rain should be kept over the seedlings for about three weeks after they have been pricked out. Root pruning should begin after winter, and repeated every 3–4 weeks. At the time of the first root pruning the pots should be spaced out with 5–10 cm between the rows. The best size of seedlings for planting is 20–30 cm tall, with root collars more than 2.5 mm diameter. Below 1800 m they will require 12 months in the nursery; above this, 16 months, or at very high elevations, 28 months to more than two years.

Performance in plantations and rates of growth

Under good conditions plants can be expected to reach about 2 m in height after three years, and grow faster thereafter, but growth rates are likely to vary considerably with soil and altitude. At Tistung (1930 m) in a trial at 28 months old there were 87 per cent survivors with a mean height of 1.7 m from a provenance from Nagarjung, Nepal, and 66 per cent, mean height 1.2 m, from a Darjeeling, India, provenance. The Darjeeling provenance had leaf curl on the topmost shoots. At Kharidunga (2400 m) trees 4.5 years old only averaged 0.7 m in height. In India naturally grown trees of *B. alnoides* had a mean annual diameter increment of between 5 and 8 mm. '*Betula cylindrostachya*' in the Darjeeling Hills had, at the age of nine years, a mean diameter of about 13 cm and a height of 16 m; and at 30 years, a diameter of 32 cm and a height of 37 m, with a mean annual increment of about 15 m³ ha⁻¹ (Troup, 1921).

Provenances

Although the Enumeration includes *Betula cylindrostachya* as a synonym of *B. alnoides*, of which it is an eastern form, there is evidence that it differs from typical *B. alnoides* in its ecology and growth rates. It grows at lower altitudes than *B. alnoides* and in the Darjeeling area even descends into the Terai along streams. It also appears to grow faster, though this may be due to warmer weather at lower altitudes. '*B. cylindrostachya*' would be worth trying at altitudes between 1000 and 1500 m in eastern Nepal. At higher altitudes it is less satisfactory, and, as described above, at Tistung a local provenance of *B. alnoides* did better than a Darjeeling one.

Uses

The wood is grey, light brown, or white, and is hard and close-grained. It weighs about 650 kg m⁻³, and is a good fuel. It has been suggested for use in making matches. In India it is regarded as an excellent timber for the insides of furniture, plywood, and tool handles. The leaves are used as fodder where the tree is found, but only on a small scale; the crude protein is about 19 per cent of the dry matter content (D. Bajracharya *et al.*, 1985). At one time the bark was used for writing on.

Importance in Nepal

Betula alnoides has so far not been planted on a very wide scale. It could be a useful species within its natural range, though it grows better below 2000 m.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhaney and Joshi (1980); Napier and Robbins (1989); Suri and Seth (1959); Trotter (1958); Troup (1921).

***Betula utilis* D. Don**

(Syn. *B. jacquemontii* Spach)

This is the higher altitude birch of Nepal and indeed one of the trees growing at the highest altitudes of all, up to the tree line at over 4000 m. Its lower natural limit is at about 2700 m. Over much of its range it is dominant in a belt just below the tree line, but in some places it tends to be mixed with *Rhododendron*, and in the Humla-Jumla region it is frequently associated with *Abies* species and *Pinus wallichiana*, and is particularly characteristic of gullies where the snow lies for a long time. The seed ripens between August and October, and is sown then, being left to stratify naturally over winter. There are about 2.5 million seeds kg⁻¹. Germination of fresh seed is 32 per cent, of stratified seed 65 per cent (M.W. Campbell, 1983a). At the altitudes where it is likely to be planted it will probably need at least two years in the nursery. Otherwise nursery treatment is the same as for *B. alnoides*.

In trials its growth has been slow, and survival often poor. At Kharidunga (2500 m) mean height was 74 cm after 4.5 years; at Tistung (1900 m) survivors 38 per cent and mean height 63 cm after 2.3 years; at Nagarkot (1700 m) survivors 40 per cent and mean height 73 cm after 1.3 years. Its rate of growth in natural forest is slow, with a mean annual diameter increment of about 3 mm.

The timber is used for agricultural implements such as threshing sticks, and as fuelwood. The bark is widely used in waterproofing roofs, insulating cracks in walls, and making bottle stoppers. It also has medicinal uses, for treating wounds, and about 40 t are collected each year (Manandhar, 1980). The timber weighs about 700 kg m⁻³. Over much of its range natural forests are adequate, if protected, to provide local needs and hence it has not been planted very much, except in the Sagarmatha National Park.

References: Gamble (1922); Troup (1921).

Boehmeria Jacq.

Urticaceae

Boehmeria rugulosa Wedd.

Nepali: dar, githi.

A small to medium tree. Leaves alternate, long pointed, with toothed margins and three prominent veins; lower surface white velvety. Flowers small, greenish-yellow, in thin pendulous spikes 5–15 cm long. It grows in Nepal from 300 to 1700 m, and is most common in the higher elevation *Shorea robusta* forests, and in *Alnus nepalensis* forests at about 1500 m. It is found naturally on dry slopes, and often accompanies *A. nepalensis* in colonizing landslips. It is not frost-hardy. The seed ripens between October and January, and is said to be viable for 3–4 months. It is light and about 1 mm long. Different nurseries have produced from 2000 to 80,000 plants kg⁻¹ of seed. In the nursery the techniques for small-seeded species should be used. At about 1500 m sowing in September to October would appear to be the best time, but more information is needed. It can also be propagated from cuttings.

There have only been a few trials. In a two-year-old trial at Murtidhunga, near Pokhara, above 1500 m, survival was 72 per cent, and mean height 36 cm; it failed at Salle at over 2000 m. These results indicate that it is not very good at higher altitudes. In India, in natural forest, its growth is fast, with a diameter increment of between 1.0 and 2.5 cm yr⁻¹ (Gamble, 1922).

It is a good fodder, of considerable importance locally. It can be lopped more than once a year. The leaves fall between mid-March and mid-May, and flush mostly from mid-April to mid-June. In southern Lalitpur District it is one of the fodders most widely used by farmers especially in February, but its importance elsewhere varies a good deal. The crude protein content of the leaves is about 8 per cent of the dry matter (D. Bajracharya *et al.*, 1985). The wood is valued for making containers for milk and other materials; its specific gravity is about 0.65. It is worth trialing on a wider scale in Nepal, particularly at altitudes of between 1000 and 1500 m.

References: Gamble (1922); Panday (1979; 1982); Upadhyay (1991); Upton (1990).

Seven other species of *Boehmeria* occur in Nepal, mostly shrubs and climbers.

Bombax L.

Bombacaceae

Bombax ceiba L.

(Syn. *B. malabaricum* DC, *Salmalia malabarica* (DC) Schott & Endl.)

Nepali: simal.

Red Silk-Cotton.

Large deciduous tree. Branches horizontal; young stems covered with prickles. Leaves alternate, digitate, with 5 or 7 leaflets. Flowers appearing when tree is leafless, large, scarlet. Fruit a hard woody capsule, about 10 cm long; seeds embedded in dense wool.

Natural occurrence

Mainly in the Terai, as a constituent of *Shorea robusta* forests, but occasionally extends to higher elevations, up to 1500 m in India. It is often the only tree left in villages in the Terai.

Silvicultural characteristics

A large tree, up to 40 m high by 2 m in diameter. The stem has buttresses at the base. The tree is a strong light-demander. Its best growth is on deep, rather sandy alluvial soils, and on such sites it will withstand seasonal flooding; on badly drained sites its growth is stunted. On stiff clay growth is poor. The seedlings are killed back by frost, though they may sprout again; however this results in poor growth, and *B. ceiba* should not be planted in frosty areas. Fire has a similar effect; the seedlings may be burnt back annually, but will sprout from the base, until eventually a stem is formed. Once a stem has been established the thick bark reduces the risk of further damage by fire. This dieback and sprouting of seedlings also occurs under poor soil conditions and may be repeated for several years before a stem develops; *Shorea robusta* shows similar behaviour. Browsing causes considerable damage. The tree coppices well when small, but not later. It produces abundant root suckers.

Natural regeneration

The seed, surrounded by masses of white hairs, is dispersed by the wind. Seedlings often come up in clumps of dense thorny shrubs, or in tussocks of grass, where they get some protection against grazing. They also colonize abandoned cultivation. Their growth is greatly impeded by dense weed growth. Protection against fire greatly helps the establishment of young seedlings.

Artificial regeneration

Seed

The seed ripens in April and May. The ripe pods should be knocked off the tree before they are about to open. There may be difficulties in collecting seed from the trees where they are heavily lopped. The pods are placed in the sun until they burst. The seed can be separated from the floss by putting it in sacks and beating them with sticks, or by using a stick with two pointed cross pieces, at right angles to each other, at the end. Twirling this in the mixture of seed and floss in a basket or other container will cause the seeds to sink to the bottom of the basket. The floss is of commercial value and should be collected and sold. During cleaning and other operations a screen should be placed around the pods to prevent the seed being blown away by the wind. One hundred dry pods weigh about 2 kg, and produce about 600 g of seed and 450 g of floss. There are between 21,000 and 45,000 seeds kg⁻¹.

After having been well dried, the seeds can be stored in sealed containers, preferably plastic bags, for a year, though viability is reduced under storage. In trials in India seed stored in sealed tins for a year gave germination percentages of 45–70 per cent of fresh seed. Seed stored in sacks loses its germinative capacity rapidly. In some localities there are good seed crops every year, in others abundant seed is only produced in one year out of two, on average. The seed does not need any treatment before it is sown. Boiling water treatment reduces the germination percentage. Germination takes from a few days to about four weeks. Germination of fresh seed may be 50 per cent or less. In India between 6000 and 14,000 plants can be raised from 1 kg of seed.

Nursery and plantation techniques

To raise plants in polythene pots, two or three seeds should be sown directly into each pot with shade being given for about two weeks after the seeds have germinated. In the Terai sowing in March or even later will give plantable stock by the onset of the monsoon. Troup (1921) writes that in Dehra Dun seedlings two months old were planted, and by that time they had developed taproots 20–30 cm long. This emphasizes the importance of regular root pruning; even so, keeping plants in pots for more than two or three months may be harmful, unless very large pots are used, as is recommended by M.W. Campbell (1983a).

Bombax is commonly planted as stumps in India, from one-year-old nursery stock which yields stumps of 0.8–2 cm diameter at the root collar. Experiments have shown that stumps of 0.8–1 cm diameter survived after planting as well as, or better than, larger stumps. Very large cuttings, up to nearly 2 m long by 5 cm in diameter, are sometimes used by the local people, but survival of these cuttings is usually low, less than 20 per cent.

Direct sowing in plantations is often used in India, usually in conjunction with the raising of agricultural crops (taungya). The seed is sown either in hoed lines, or in prepared spots; in the latter case about five seeds are sown in each spot. Once the seedlings are established they are thinned out to one per spot, and the surplus used to plant up blank spots where necessary.

Bombax has a very wide spreading crown and for rapid growth should be planted at a wide spacing of 5 m x 5 m or more, especially as thinnings are of relatively little value. The intervening spaces could be used for growing a fast-growing fuelwood species, or for agricultural crops. Plantations need to be well weeded for the first two years; after that the trees are large enough to withstand competition.

Pests and diseases

In the nursery the growing tips of the seedlings are often eaten out by insects; this may need to be controlled by spraying with an insecticide, such as metacid. Trees in plantations are sometimes attacked by the fungus, *Ganoderma lucida*, which causes root rot.

Rate of growth

Under favourable conditions growth is rapid, and in very good conditions the trees can reach a diameter of 38 cm in ten years. Average quality *B. ceiba* in Uttar Pradesh reaches 15 cm diameter and 10 m in height in ten years, and 32 cm in diameter and 18 m in height in 20 years. A general volume table has been published by E.R. Sharma and Pukkala (1990b).

Uses

In Nepal it is used mainly for match manufacture, though it is only a fair quality match timber (Dey and Ramaswami, 1960). The timber is creamy white or pale pink in colour, soft, very easy to work, but very perishable. In India, in addition to matches, it is used for packing cases, toys, and cheap plywood. It is light in weight, between 250 and 500 kg m⁻³, though it has a fairly high calorific value, 20,500 kJ kg⁻¹. It would not be considered a good fuelwood species. The leaves are a medium-quality fodder and in some localities the trees are heavily lopped. The fruits produce a floss which is used for stuffing pillows. The young flowers can be eaten as a vegetable, but this is not common in Nepal. The roots and gum are used medicinally.

Importance in Nepal

Its main importance in Nepal used to be as raw material for the match manufacturing industry, which up to the present has largely depended on *Bombax* from

natural forests where supplies are becoming exhausted. Plantations to replace the natural trees could be established either by the match manufacturers or other bodies. However it is possible that poplar may eventually replace *Bombax* for match manufacture (Matela, 1984). The tree grows fast on suitable sites, and so fairly short rotations are possible.

References: M.W. Campbell (1983a); Choudhury and Ghosh (1958); Gamble (1922); Ghosh (1977); H.B. Joshi (1980); Lamichhaney and Joshi (1980); Napier and Robbins (1989); R.V. Singh (1982); Trouer (1958); Troup (1921); Venkataramany (1968a).

***Brassaiopsis* Decne. & Planch.**

Araliaceae

***Brassaiopsis hainla* (Buch.-Ham. ex D. Don) Seem.**

Nepali: chuletro, seto chuletro.

Small evergreen tree, with prickly branches. Leaves palmately lobed to less than halfway down, lobes triangular, toothed. Flowers small, greenish, in spherical umbels. Fruit a berry, about 8 mm in diameter. *Brassaiopsis hainla* occurs in Nepal between 800 and 2000 m, but is commoner between 1200 and 1600 m. At higher altitudes it tends to be replaced by *B. glomerulata*, although their ranges overlap.

The seed ripens in May to June. The ripe fruits are black, about 8 mm in diameter, and each fruit contains two or three seeds. These should be extracted by soaking the fruit in water until the flesh is soft, and then gently rubbing them together; the seeds should not be allowed to dry out. There are from 25,000 to 35,000 seeds kg⁻¹. The seed is recalcitrant, and should be sown as soon as possible after extraction. The germination rate of fresh seed is about 80 per cent but plant percentages achieved in nurseries indicate considerably lower germination or poor survival in the nursery; about 1200 plants kg⁻¹ of seed is an average figure. The seed should be sown directly into polythene pots (poly-pots), with two seeds per pot; if there is doubt about the percentage germination some extra seed should be sown in boxes for pricking out into pots later. The seed germinates after 2–3 weeks. Shade is not essential for the young seedlings, but protection against heavy rain is necessary, as the seed is sown towards the beginning of the monsoon. Frequent root pruning is important, and the seedlings should be spaced out at the end of the cold season.

The short viability of the seed necessitates sowing in May or June. At lower altitudes by the time the planting season arrives in June or July the next year the seedlings will be 10–20 cm tall, but with a root-collar diameter of more than 6 mm, and with masses of fibrous roots growing along one to three main roots. Such seedlings though rather short should be plantable. At higher altitudes an extra year in the nursery will be needed. Seedlings in the nursery are very liable to damage by grasshoppers.

Farmers traditionally propagate it from two-metre-long branch cuttings. In Hetauda hardwood cuttings 20–30 cm taken in February, and set within 24 hours of cutting, rooted successfully (more than 50 per cent). Very satisfactory results were also obtained at Lumle from cuttings 30–45 cm long set during the last week in March (Napier, 1988). In view of the short viability of the seed and the slow growth of seedlings in the nursery the use of cuttings has much to recommend it. The use of natural seedlings transferred from the forest to polythene pots in the nursery in August has also been found to be satisfactory. The best time for this is when the first true leaf of the seedling is about 2.5 cm long.

There is not much data available about growth in trial plots or plantations, and what there is comes from altitudes over 1600 m which is above the optimum for this species. The best result came from Tistung (1900 m) where trees planted under pines had 92 per cent survival and a mean height of 96 cm after 2.5 years. Elsewhere both survival and height growth was much poorer. Results from lower altitudes, and from plants raised as cuttings, would be interesting.

Its main use is for fodder, for which it is locally in high demand by farmers. Its leaves have a crude protein content of about 22 per cent (Panday, 1982), 7.6 per cent of dry weight (D. Bajracharya *et al.*, 1985) and a dry matter digestibility value of more than 50 per cent. Their tannin content is low (Wood *et al.*, 1992). Cattle also eat the bark from the branches (Heuch, 1986). The tree can be lopped between the end of October and the beginning of April, but is preferred mainly for feeding before the monsoon. It is evergreen, with new leaves appearing in April to May. The estimated annual yield of fresh fodder per tree is 40–60 kg (Panday, 1982).

***Brassaiopsis glomerulata* (Blume) Regel**

(Syn. *B. speciosa* Decne. & Planch.)

Nepali: kalo chuletro.

A small tree usually with a single stem; stem prickly. Leaves digitately divided into a number of separate leaflets, arising at the end of a long common leaf

stalk. Inflorescence over 30 cm long, of numerous many-flowered umbels. Fruit almost spherical, about 8 mm in diameter. It usually grows at higher altitudes than *B. hainla* though their ranges overlap. However, it is not completely frost-resistant: 96 per cent of the seedlings planted on an exposed slope at Pakhribas (1900 m) died, and poor results have been obtained on exposed sites elsewhere.

Its seed ripens in April, and about a thousand plants have been raised per kilogram of seed in community forestry nurseries. Seed and nursery treatment are similar to that of *B. hainla*. In the Phewa Tal Watershed Project the seeds were sown in raised beds under shade, and pricked out into containers at the four-leaf stage, but direct sowing into polypots is also possible. At altitudes below 1400 m, 3–4 months in the nursery are enough, provided seed can be sown early enough. Like *B. hainla* it can also be raised from hardwood cuttings; in the Phewa Tal area, Pokhara, such cuttings 2 cm in diameter and 40 cm long were successfully planted directly in the field during the monsoon (Mulder, pers. comm.). It is a useful fodder tree. In Dhankuta District green weight per tree, lopped between December and February, ranged from 10–85 per cent, with a dry/fresh weight ratio of 33 per cent (Oli, 1988).

Brassaiopsis polyacantha (Wall.) Banerjee, (syn. *B. palmata* (Roxb.) Kurz), dangdinge, is a thorny-stemmed plant suggested as suitable for hedges, and as a source of fodder. It resembles *B. hainla*, but its leaves are divided halfway down or more into 5–7 parallel-sided lobes. It occurs between 700 and 1850 m. The seed ripens in the monsoon, and should be sown immediately after collection, using similar techniques to those for other *Brassaiopsis* species. It can also be raised from hardwood cuttings 30 cm long and 2 cm thick taken in February and March (M.W. Campbell, 1983a).

Brassaiopsis mitis C.B. Clarke resembles *B. polyacantha*, but the leaves are divided into 9–13 lobes. It is confined to eastern Nepal. *Brassaiopsis aculeata* (Buch.-Ham. ex D. Don) Seem. has separate leaflets, like *B. glomerulata*, but the leaflets are distinctly toothed, and the twigs covered with dense rusty hairs.

References: M.W. Campbell (1983a); Kessler (1981); Napier and Robbins (1989); Panday (1979; 1982).

Bridelia Willd.

Euphorbiaceae

***Bridelia retusa* (L.) Spreng.**

Nepali: gayo.

A medium to large deciduous tree. Young stems often with stout blunt thorns. Leaves alternate, leathery, with straight parallel veins, margins without teeth. Flowers small, greenish, in clusters about 8 mm in diameter in the leaf axils. Fruit a drupe about 8 mm in diameter, containing one or two seeds. In Nepal it occurs up to about 1200 m, and is a common associate of *Shorea robusta*. It will withstand moderate shade; the seedlings are somewhat frost-sensitive, but often recover after frosts. It is moderately drought-resistant and is capable of surviving on dry shallow soil. It coppices well and produces root suckers. The fruits are eaten by birds which spread the seed. The fruits ripen between November and March, and turn purplish-black when ripe. Each fruit contains one or two rather bony seeds, of which 10,000 to 18,000 weigh 1 kg. The viability is rather short, about six months. Fresh seed has a germination percentage of about 75, but the number of plants raised in nurseries from 1 kg of seed has been as low as 400. The pulp should be removed from the seeds before they are sown, and they should be soaked in cold water for 24 hours.

Growth rates in the nursery are rather slow; it takes a year for the seedlings to reach 15 cm in height. The seedlings benefit from shade when young. They are deciduous and are leafless from December to February. It is also possible to raise *B. retusa* from hardwood cuttings 20–30 cm long and 1 cm thick, taken in the dormant season between December and January. Early rate of growth in plantations appears to be rather slow; plants at Trisuli 21 months old averaged about 50 cm in height. In natural forest the mean annual diameter increment ranges from 1.2 to 10 mm. The rate of growth of coppice is about equal to that of *Shorea robusta*.

The leaves are considered to be of medium to good quality as fodder; they contain from 14 to 18 per cent crude protein. However the newly flushed leaves are somewhat toxic. They are locally moderately important as fodder, for instance at Ratanpuri at the foot of the Siwaliks (Upadhyay, 1991); elsewhere they are used sporadically. The wood is rather hard, close-grained, and grey to olive-brown in colour. In India it is used for agricultural implements, carts and buildings. It weighs about 830 kg m⁻³.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); R.V. Singh (1982); Trotter (1958); Troup (1921).

Three other species of *Bridelia* occur in Nepal. *Bridelia pubescens* Kurz. and *B. tomentosa* Blume are small trees found in eastern Nepal, below 700 m.; *B. stipularis* (L.) Blume is a woody climber.

Broussonetia L'Herit. ex Vent.

Moraceae

Broussonetia papyrifera (L.) Vent.

Paper mulberry.

A middle-sized deciduous tree. Leaves 10–20 cm, rough on upper side, ovate or lobed. Male flowers in pendulous cylindrical catkins; females in spherical heads. Fruiting carpels protruding from the heads on long fleshy stalks, turning orange-red. This species, whose native range extends from Burma to Thailand, China, Japan and Polynesia, has been suggested as a possible substitute for *Daphne* for use in the indigenous paper-making industry. Its date of introduction is not known, but there were vigorously growing specimens near the Research Nursery at Hetauda in the 1980s.

The tree grows best on moist fertile soil, and on such sites will withstand a certain amount of waterlogging; however it has also grown well at Adabhar, which is only moderately fertile. It is said to grow badly where there is heavy grass competition. In Japan it grows in areas subject to annual frosts, and at least some provenances are frost-hardy in Europe, but in such a wide ranging species differences in provenances may be expected. It needs full light. It coppices vigorously and produces very abundant root suckers, to such an extent that once established it may become difficult to eradicate.

Attempts at propagation by hardwood cuttings have so far not been very successful; only two or three cuttings rooted successfully at Hetauda. In Europe softwood cuttings, taken in summer, are used. Root cuttings are also recommended. There is not much experience in Nepal of raising it from seed. There are about 700,000 seeds kg⁻¹, but only about four per cent viability. The methods for small-seeded species should be used. Its growth is very rapid on good sites, with an annual diameter increment of up to 5 cm. For paper making it could be worked on a short coppice rotation of 3–5 years.

The bark is used for paper making in a number of countries, including Thailand, China and Japan, and provides the traditional bark cloth of Polynesia.

Trials have also been made for using the whole tree for paper making. The wood is soft and light, weighing about 380 kg m^{-3} . In China the leaves are fed to pigs. As far as is known, trials have only been made at low altitudes. For consideration as a substitute for *Daphne* for traditional paper making there should be trials at higher altitudes as this is where the traditional paper makers live.

References: Gamble (1922); Jeanrenaud (1984b); Troup (1921).

Bucklandia populnea see *Exbucklandia populnea*.

Buddleja L.

Buddlejaceae

Buddleja asiatica Lour.

Nepali: bhimsen pate.

A large evergreen shrub. Leaves opposite, underside covered with dense grey felty hairs. Flowers white, fragrant, in long dense cylindrical clusters up to 15 cm long. Fruit dry, hairless, about 4 mm long. It occurs in Nepal between 350 and 2000 m, as an understorey in *Shorea robusta* and pine forests. It is also common on waste land, for instance around Kathmandu. The fruit appears in April and ripe seed may be collected up to the end of May. It is minute, about 20 million seeds weighing 1 kg. It should be dried in the sun, and stored in sealed plastic bags, when it will retain its viability for at least a year. It should be sown in beds or trays, using the techniques for small-seeded species; the plants are pricked out into plastic pots when they are about 2 cm tall. Plantable stock can be raised in about four months at lower altitudes. It can also be raised from short side-shoot cuttings taken in July, and from 150–200 cm stem cuttings.

Very little information is available about growth rates. In a trial seven years old at 1800 m in the Lumle area, survival was 70 per cent and mean height 1.7 m, but the shrub rarely reaches large dimensions. It is mainly valued as a fodder, and is popular for this purpose among farmers in some districts. Although its yield of fodder is not very high it has a small crown and so causes relatively little damage to crops by shading. The leaves contain about 20 per cent crude protein, and have a high calcium content (1.6 per cent). The Ca:P ratio is high, which is not favourable. Eating the leaves causes dysphagia, and in some places they are not used if other fodder is available. Fodder is available

between October and March, with the new leaves flushing in April and May; the annual yield in fresh matter from one tree is between 20 and 80 kg.

References: M.W. Campbell (1983a); Lamichhane and Joshi (1980); Panday (1982); R.K. Shrestha and Gautam (1991).

Calliandra Benth.

Mimosaceae

Calliandra calothyrsus Meissn.

A small evergreen tree, usually with many stems. Leaves bipinnate. Flowers crimson, with many long protruding stamens, looking like powder puffs. Fruit a pod. Native to Central America. It has been planted on a large scale in Indonesia and other countries in the humid tropics, as a very high-yielding source of fuelwood; in such conditions it can reach a height of 2.5–3.5 m in less than a year. Its growth is less spectacular in areas with a pronounced dry season. At Adabhar, in the Bhabar Terai, trees of an Indonesian provenance when 18 months old had a survival rate of 70 per cent, and averaged 3 m in height, with a root collar diameter of 6 cm. Growth of a Guatemalan provenance was slightly less. These results are tolerably good, but are exceeded by such species as *Acacia auriculiformis*. At higher altitudes results are poorer. The leaves contain 22 per cent protein and yields in Indonesia are 7–10 t ha⁻¹ yr⁻¹ dry weight of leaves. Thus it has some potentiality for fodder production. It is being tried as a possible substitute for *Leucaena*, but more information is needed before this can be evaluated.

References: National Academy of Sciences (1979).

***Callistemon* R.Br.**

Myrtaceae

***Callistemon citrinus* (Curtis) Skeels**

(Syn. *C. lanceolatus* (Smith) Sweet)

Nepali: kalki phul.

Bottle brush tree.

A small evergreen tree with a rough bark. Leaves alternate, stiff, 3–8 cm by about 6 mm. Flowers red, with long stamens, in dense cylindrical inflorescences. This Australian tree is widely planted in the tropics, including Nepal, as an ornamental and avenue tree. It has been raised in a number of community forestry nurseries for distribution to local people. The tree can be successfully grown from the Terai to about 1800 m. It is said to tolerate swampy and seasonally flooded areas, and in Britain does badly on shallow chalky soils (Hillier and Sons Ltd, 1981), but these statements need confirmation under Nepalese conditions. The seed ripens between September and March, and there are about 850,000 seeds kg⁻¹ of which, however, about 60 per cent are likely to be aborted. In community forestry nurseries the equivalent of about 20,000 seedlings kg⁻¹ of seed has been raised. To ensure seedlings of plantable size by the onset of the monsoon, the seed should be sown in September to October above 1000 m and in March to April below 1000 m. The nursery techniques used for raising eucalypts are appropriate. *Callistemon* can also be raised from cuttings (Macmillan, 1956). The wood is reddish or brown, hard and close-grained, weighing about 800 kg m⁻³. Other species of *Callistemon* may be seen in gardens in Nepal.

References: M.W. Campbell (1983a); Gamble (1922).

***Cassia* L.**

Caesalpiniaceae

Trees, shrubs and herbs, with even pinnate leaves. Flowers yellow or pink, often showy. Petals five. Stamens usually unequal, some long, some short. Fruit a pod.

***Cassia siamea* Lam.**

Tree with smooth grey bark. Leaflets 6–10 pairs, elliptic, 4–6 cm long. Flowers yellow in large panicles. Pods flattened.

Natural occurrence

This species is not native to Nepal, but occurs in southeast Asia from Burma to Indonesia. It has been widely planted in tropical countries.

Silvicultural characteristics

It prefers well-drained fertile soils, although as it is shallow rooting, it will grow over laterite provided this is more than about a metre below the surface. It does not thrive on swampy sites, or in areas with a heavy growth of *Imperata*. Young plants are subject to browsing damage by domestic animals. They are killed by fires, but will shoot again from the base. The tree coppices freely and produces root suckers. In the Bhabar Terai it tends not to have a single main stem; it has a spreading crown and many branches. It has a spreading root system, and competes strongly with other species; competition in pure plantations also sets in early, so wide spacing is desirable. Once established the heavy crown eliminates grass competition. *Cassia siamea* does not form root nodules with *Rhizobium* species, and hence does not fix nitrogen.

Artificial regeneration

Seed

The seed ripens between December and April; the pods should be collected after they have turned brown but before they open. The seed is extracted by drying the pods in the sun, and then beating them with sticks. There are 30,000–40,000 seeds kg⁻¹. The seed is orthodox and should be stored in sealed polythene bags after having been thoroughly dried. It retains its viability for many years. Before being sown the seed should be treated, otherwise germination is slow and irregular. For small quantities manual scarification, by clipping off a small portion of the seed coat at the opposite end to the hilum, is effective. For larger quantities the seed should be immersed for 15–30 seconds in 15 times its own volume of water that has just boiled and been removed from the heat, and then soaked in cold water for 24 hours. Napier (1987c) found that scarified seed had 72 per cent germination, and that treated by hot water 45 per cent. In both cases germination began four days after sowing and was virtually complete eight days later.

Nursery and plantation techniques

Generally in Nepal, *C. siamea* has been planted as seedlings raised in polypots, but stumps have also been successful, and direct sowing in plantations is

practised in other parts of the world. For raising seedlings in polypots, two treated seeds should be sown in each pot, in the standard mixture of three parts of soil to one of sand. Surplus seedlings should later be removed. The seedlings in the pots should be spaced out with 5–10 cm between the rows of pots. Root pruning should begin 4–6 weeks after sowing, and continue every two or three weeks until the seedlings are planted. The seedlings develop very strong taproots with abundant laterals, and it is essential that holes are cut in the polypots, and that root pruning is not neglected. In the Terai proper the seedlings will need 10–12 weeks in the nursery; in the Bhabar Terai and the inner Terai (dun valleys), 12–14 weeks. This will produce sturdy seedlings about 25 cm tall, with a root collar diameter of 2.5–3.5 mm.

For raising stumps, treated seed should be sown in beds in February in lines 15 cm apart. One month after germination the seedlings should be thinned out to 15 cm between plants. Provided the nursery soil is good the plants should be 100–150 cm tall with a root-collar diameter of 5–15 mm by July.

A number of techniques for direct sowing are possible, but unless very plentiful supplies of seeds are available, sowing in prepared pits, into which the soil has been replaced, at the rate of about four seeds per pit is recommended. The pits should be at the normal plantation spacing. This method uses less seed than line sowing. The very small seedlings will not tolerate grass competition and need to be weeded well. This technique has been successfully used in east Africa and Sudan.

Even for short-rotation, fuelwood plantations wide spacing is desirable; Hawkins (1987b) recommends 2 m x 5 m. Very close spacing reduces increment considerably. Clean weeding, or intercropping, during the first two years is essential if good growth is to be obtained. Thereafter *Cassia* develops a heavy crown and eliminates grass.

Performance in plantations and rate of growth

In well-tended plantations in the Terai and Bhabar Terai its early growth is rapid; in many trials only *Acrocarpus* and the faster-growing eucalypts have grown faster. The following are some of the better results: Adabhar, 18 months old, survivors 98 per cent, mean height 4.0 m, root-collar diameter 6.1 cm; Sagarnath, on a good site, 21 months old, mean height 6.3 m; Butwal, 30 months old, survivors 94 per cent, mean height 7.5 m, dbh 4.9 cm. At Adabhar 18 months old plantations, with 10,000 trees ha⁻¹, had a mean annual increment of 9.7 t ha⁻¹ oven dry weight of fuelwood, but this spacing was considered to be too close (Hawkins, 1986).

It has been tried at Adabhar in one to one mixture with *Eucalyptus camaldulensis*; the *Eucalyptus* was planted at 3 m x 3 m and the *Cassia* alternated

with them. The aim was to reduce the need for weeding the eucalypts and to provide an early return of fuel from the *Cassia*. Half the *Cassia* trees were cut every winter from the second year onwards and the subsequent coppice growth singled out. At the second thinning of the *Cassia*, at 30 months old, the air-dry mass of wood per tree was 11.1 kg, and of leaves 4.2 kg. Assuming 1000 surviving *Cassia* trees ha⁻¹, of which half were removed, this is equivalent to about 5.5 t ha⁻¹ wood and a little over 2 t ha⁻¹ leaves (R. Shakya, 1990).

In a second unreplicated trial, comparing the effect of mixing different species with *E. camaldulensis*, the *Cassia* appeared to depress the growth of the *Eucalyptus*, which at 18 months old, averaged 5.9 cm dbh, as compared with 7.9 cm for the control plot of pure *Eucalyptus* (R. Shakya, 1990). Several years later this suppressive effect could still be seen. Against this, planted in mixture with *Acrocarpus fraxinifolius*, at 18 months old, it appears to have improved growth of the *Acrocarpus*, which when pure averaged 6.1 m tall and 6.5 cm dbh, and when mixed with the *Cassia* 6.4 m tall and 7.7 cm dbh. It is only suitable for planting at low altitudes; for instance it failed at Syangja (1100 m). Biomass and volume tables for young *Cassia siamea* have been produced by Hawkins (1987a; 1987b).

Pests and diseases

In 1984 at Adabhar trees were severely defoliated for several months by an unidentified leaf-eating caterpillar, with serious effects on growth. No other records of this type of attack have been seen, and it is assumed to be sporadic.

Uses

It produces a good fuelwood, with a density of about 470 kg m⁻³ for trees 2.5 years old, and this is expected to increase as the trees grow older. The timber is rarely available in large sizes; it is used for such purposes as tool handles. The heartwood, which begins to form at the age of three or four, is dark brown to black, and very decorative. The leaves are not palatable to cattle, but can be used for bedding and compost.

Importance in Nepal

If its early promise is maintained it is of considerable promise as a source of fuel in the Terai, especially for village woodlots and private plantations. Its growth is inferior to that of the better eucalypts, but it is rather easier to establish and eliminates grass early, which eucalypts do not. There has been a tendency, however, in other countries, to move away from planting *Cassia siamea*. For instance thirty or forty years ago it was quite widely planted in tropical Africa, but nowadays is often replaced by species of *Eucalyptus*.

References: Anon. (1983c); Gamble (1922); Ghosh (1977); Laurie (1974); Letourneux (1957); Magini and Tulstrup (1955); Napier and Robbins (1989); National Academy of Sciences (1979); Rao and Purkayastha (1972); Streets (1962); Webb *et al.* (1984).

***Cassia fistula* L.**

Nepali: rajbriksha, amaltas.

A middle-sized to large tree. Leaflets 4–8 pairs, ovate, pointed, 5–13 cm long. Flowers yellow, in long hanging racemes. Pod cylindrical, up to 90 cm long, black. Native to Nepal, from the Terai to 1400 m, and also often planted as an ornamental tree. There are about 6300 seeds kg⁻¹. The seed can be stored for more than ten years, but stored seed is liable to insect damage. One-year-old seed is said to germinate better than fresh seed. Seed treated with hot water should be sown directly into polypots in March or April, and will produce plantable stock by the monsoon. In natural forest its rate of growth is rather slow, but no information is available about growth in plantations. Trees planted for ornament in gardens grow fast. It produces a good fuelwood (970 kg m⁻³). It is also used medicinally.

References: M.W. Campbell (1983a); Ghosh (1977); Lamichhane and Joshi (1980); Magini and Tulstrup (1955); Streets (1962); Troup (1921).

Other species of *Cassia* in Nepal are herbs or weak shrubs.

***Castanea* Mill.**

Fagaceae

***Castanea sativa* Mill.**

Nepali: deshi katus.

Chestnut.

Large tree with ridged bark. Leaves with toothed margins and numerous prominent parallel veins. Flowers in catkins. Fruit enclosed in a cup covered with long spines. A native of southern Europe and western Asia, widely planted in temperate countries for its edible nuts and its timber, which has been introduced into Nepal. There are one or two trees at Singha Durbar, Kathmandu, and there is a small orchard at Kakani (2000 m), where it grows well and produces fruit. Its fruit has also been reported from Ilam District (Regmi, 1982) and it has been

tried in Dolakha District where initial growth was good, and it was expected to begin to produce fruit after seven years (Schaltenbrand, 1982). In India it does best between 900 and 1500 m, where it prefers sandy but deep and fertile soils (Troup, 1921). It is moderately lime-tolerant, and frost-resistant. It coppices very freely.

There are about 240 seeds kg^{-1} in Europe, but the seed produced in India and Nepal tends to be smaller. The seed ripens about October in Nepal. It should be treated like the seed of *Quercus*, and stored over winter in moist sand in jars or pits. In India it is said not to store well, and sowing soon after collection is recommended, but at higher altitudes seed sown at this date is unlikely to germinate before the next spring. In Dolakha District the technique used was to sow the seeds in beds at a spacing of 30 cm x 30 cm, and plant out bare-root plants in February. This is similar to the technique used for *Juglans*. The plants will need about 12 months in the nursery if they are planted out in winter, or about 16 months if planted in the monsoon.

The edible nuts are greatly prized and at one time were an important item of diet in parts of Europe. The timber weighs about 560 kg m^{-3} . In Europe it is used for constructional timber, and it is also grown on a coppice rotation for small poles, or split to make fencing. The tree is worth further trial as a multipurpose species in the hills of Nepal.

A hybrid between *C. sativa* and *C. crenata* Sieb. and Zucc. was planted at Dandapakhar, Dolakha District, in 1981, but the results are unknown.

References: Gamble (1922); Gordon and Rowe (1982); Troup (1921).

Castanopsis (D. Don) Spach

Fagaceae

Nepali: katus.

Evergreen trees with alternate leaves. Flowers in erect spikes. Fruits enclosed in cupules which are usually densely covered in branched spines. Four species in Nepal, of which one is rather rare.

Key to species

- (1) Leaf margins with prominent regular teeth; fruiting cupule 2–5 cm in diameter, densely covered in sharp spines, 5–10 mm long *C. indica*
- (1) Leaf margins without teeth, or rarely with a few scattered teeth 2

- (2) Young leaves with fine reddish hairs on under side. Fruiting cupules 3–5 cm in diameter, densely covered in sharp spines 7–10 mm long *C. hystrix*
- (2) Young leaves without hairs on under side. Fruiting cupules smaller 3
- (3) Fruiting cupules with spines, arranged in bands, between which the bare surface can be seen; widely distributed *C. tribuloides*
- (3) Fruiting cupules without spines, surrounded by 4–6 wavy bands; confined to subtropical forests in the east
..... *C. lanceifolia* (Roxb.) Hickel and Camus (not dealt with further)

Castanopsis hystrix Miq.

Nepali: patle katus, bara katus.

Natural occurrence

It grows between 1000 and 2500 m, and is primarily an eastern species with its western limit near Okhaldunga. It is often associated with *Castanopsis tribuloides* and *Quercus lamellosa*. Outside Nepal it extends to Burma, Indochina, and southern China. It is frost-hardy and coppices well.

Natural regeneration

It regenerates freely in protected forests in eastern Nepal, between 1400 and 1600 m, where there is a rich dark forest soil (Sizeland, 1986).

Artificial regeneration

The seed ripens in October to November, and can be collected from beneath the trees. It can also sometimes be bought in local markets, but care must be taken not to buy seed that has already been roasted. There are about 600 seeds kg⁻¹. The seed is often damaged by insects and should be put in a container of water for 24 hours; the sound seed will sink to the bottom. The seed is recalcitrant. It may be sown immediately after collection, but if this is done it will not germinate until the warm weather of the following year, and it is meanwhile subject to losses from rodents. Thus the beds should be protected by wire mesh. If the seed is stored to be sown in March it should be kept moist by mixing it with 2–4 times its volume of damp sand, placing it in a fine wire mesh bag, or a clay pot, to protect it from rodents, and burying it in a pit 1–1.5 m deep. The seed needs a period of cold to break its dormancy. If it is sown in beds and left over winter it obtains this naturally, and also if it is stored in moist sand as

described above. An alternative method is to stratify it in a refrigerator (keeping it moist).

When the seed is ready for sowing, the simplest method is to sow it directly into polypots at the rate of one seed per pot. Large pots are essential, at least 4 inch x 7 inch lay-flat (10 cm x 18 cm), and a good quality potting mixture containing 20–25 per cent compost should be used. The seed is placed on its side in a hole in the centre of the pot and covered with about 5 mm of soil. M.W. Campbell (1983a) recommends chitting or pre-germinating the seed by sowing it densely in a seed box, and covering it lightly with leaf litter. As the seeds germinate the seedlings are removed to polypots.

The bed holding the pots should be kept shaded until the beginning of the monsoon. Root pruning should begin during the monsoon and be repeated frequently. The species forms a strong taproot, and if root pruning is neglected many deaths are likely to occur when the seedlings are removed from the nursery for planting out. An alternative is to sow the seed in beds or trays at approximately 2.5 cm spacing, and cover them lightly with soil. They should be pricked out into polypots as soon as the plumule, the embryonic shoot, emerges. As germination is hypogeal, by the time the plumule emerges the thick radicle will be well developed, and if pricking out is delayed it is liable to be damaged and the seedlings killed.

As mentioned previously, seed sown in autumn will not germinate until the next spring. If it is sown in spring it will begin to germinate about four weeks after sowing, and continue for another 3–4 weeks. The seedlings will need 15–16 months in the nursery after the seed has germinated; that is if the seed is sown in February or March the seedlings will be ready by the monsoon of the next year. Above about 2000 m an extra year in the nursery will probably be needed.

In India stumps are used, from seed sown into beds in February, at 8–10 cm spacing, and kept in the beds for about 15 months, with the roots pruned to about 22 cm three weeks before the date of planting, and the shoots pruned to about 3 cm at the time of lifting. Ordinary stumps when the roots are pruned when the plants are lifted are also fairly successful (Suri and Seth, 1959). Direct sowing is also used in India, but there are considerable risks of losses to rodents. There has been no success so far in raising *Castanopsis* species from cuttings.

Performance in plantations and rate of growth

There is not much information from trials. At Murtidhunga (1500 m) in Dhan-kuta District, survival at two years old was 75 per cent and mean height 66 cm; the young trees were growing quite vigorously. Survival in farmers plantings at

Salle in the same area was 100 per cent. In natural forest in India growth is rather slow, with a mean annual diameter increment of about 6 mm.

Uses

The timber is light greyish-brown, hard, and weighs about 740 kg m⁻³. It is good for house building, and splits readily for shingles. The leaves are used for fodder. The nuts are edible and are sold in local markets.

Importance in Nepal

In the east it is reasonably popular for planting by farmers as a fodder tree, and also for its nuts and timber. It is rather slow growing, which is a disadvantage.

Castanopsis indica (Roxb.) Miq.

Nepali: dhale katus, banj katus.

Natural occurrence

It grows between 1200 and 2900 m, and extends farther to the west than *C. hystrix*, as far as the Kali Gandaki. It is found in higher elevation *Shorea robusta* forest, and, associated with *Schima*, is very common in high rainfall areas in the Annapurna region and east Nepal. In lower rainfall areas it tends to be less common than *C. tribuloides*.

Artificial regeneration

The techniques used are similar to those for *C. hystrix*. There are about 1300 nuts kg⁻¹. Growth in the nursery is a little faster than that of *C. hystrix*, and the plants may be just large enough for planting in the monsoon if the seed is sown in the previous October.

Performance in plantations and rate of growth

It has been included in a number of trial plots, but only early results are available. Among the best were at Kadambas (1500 m) where at 18 months there was 66 per cent survival and a mean height of 66 cm, and Salle (2000 m) at two years, with survival 98 per cent and mean height 54 cm. Elsewhere growth rates have been poorer, though survival has generally been good, with the exception of Simkhara (2400 m) where it was only 40 per cent after 31 months. In natural forest growth is faster than that of *C. hystrix*, with a mean annual diameter increment of 8 to 12 mm.

Uses

The wood is light greyish-brown and hard, rather lighter than that of *C. hystrix* at about 700 kg m⁻³. It is used for buildings and shingles. The trees are commonly lopped for fodder. The leaves contain about 15 per cent crude protein and 29 per cent crude fibre, the latter figure being high. They are low in calcium (0.4 per cent) but have a satisfactory Ca:P ratio (Panday, 1976a). The tannin content is moderate. Only the mature leaves are used, often mainly for sheep and goats. They are used from December to April, and June to July. The fruit is eaten.

Castanopsis tribuloides (Sm.) A. DC

Nepali: musure katus.

Occurrence

This is the most widely distributed species of *Castanopsis* in Nepal and the only one found west of about 83°E longitude. It grows between 450 and 2300 m, being common in higher elevation *Shorea robusta* forests, in the extensive *Schima* forests between 1000 and 2000 m, and in *Quercus lamellosa* forest above 2100 m. East of the Sun Koshi River it is dominant in a belt between 1700 and 2100 m. Outside Nepal it extends from Kumaon in the west to Indochina in the east.

Silvicultural characteristics

It grows on a variety of soils, and under a large range of annual rainfall. It is said that the young seedlings are frost-tender, but with such a widely ranging species provenance differences in this respect may be expected. It coppices well and recovers vigorously when degraded forest in which it occurs is protected.

Artificial regeneration

The techniques are similar to those used for *C. hystrix*. There are about 400 viable seeds kg⁻¹.

Rate of growth

No records have been found of its rate of growth in plantations. In natural forest its growth appears to be rapid. Gamble (1922) writes that there are 2–3 rings per inch of radius, giving a mean annual diameter increment of 1.7–2.5 cm, but the rings are doubtful.

Pests and diseases

Young trees are liable to damage by the larva of a moth, *Zeuzera* sp. (Cossidae), which bores into the stems (Ivory, 1985).

Uses

The wood is grey and moderately hard, and is used for planking and shingles. It weighs about 600 kg m⁻³, but is reported to make poor charcoal (Gamble, 1922). It is not durable. The leaves contain 10–12 per cent crude protein (Panday, 1976a), 8 per cent of the dry weight (D. Bajracharya *et al.*, 1985) and have a high crude fibre content. They have a higher tannin content than those of *C. indica*. The tree is lopped for fodder between December and April, and the flush of new leaves occurs in April and May. It is estimated that one tree can produce 40–60 kg of fresh fodder each year. It is not considered as one of the best fodder trees but is widely used. Farmers value it for its high yield of leaves, and as a multipurpose tree, and rate it fairly highly for nutritional value. It is not much planted on farmers' land and most of the forage comes from the forest. The nuts are edible.

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhaney and Joshi (1980); Panday (1976a; 1982); Suri and Seth (1959); Trotter (1958); (*C. hystrix*) Troup (1921).

Casuarina Adans.

Casuarinaceae

Trees with slender, deeply grooved, jointed branchlets, with the leaves reduced to tooth-like scales at the nodes. Flowers very small, greenish, the male in spikes, the female in dense ovoid heads which become woody and cone-like in fruit. Mostly from Australia, Indonesia and Polynesia. *Casuarina equisetifolia* is also common on sandy sea shores in Bangladesh and southeast Asia. In 1982 L.A.S. Johnson split the genus, and put some species into a new genus, *Allocasuarina*. However justified this may be botanically, silviculturally and in other ways the species put in the new genus closely resemble other *Casuarina* species, and it is convenient to treat them together.

A few older trees, probably *C. equisetifolia*, are to be seen around Kathmandu. Some species, including *C. oligodon* L. Johnson and *C. cristata* Miq., which both failed completely, and some of those listed below, were tried at Chitripani and Adabhar between 1980 and 1983, without a great deal of success. Since about 1988 the following species have been tried on a number of

sites ranging from the Terai to 1600 m: *C. cunninghamiana* Miq.; *C. equisetifolia* L.; *C. glauca* Sieb. ex Spreng.; *C. junghuhniana* Miq.; *C. littoralis* Salisb. (*Allocasuarina littoralis* (Salisb.) L. Johnson); *C. torulosa* Ait. (*Allocasuarina torulosa* (Ait.) L. Johnson).

Best results were at Shankarnaga (140 m) where *C. cunninghamiana* at 16 months had 95 per cent survivors with a mean height of 1.5 m, certainly not outstanding for this altitude. At Gorlikhaka (600 m) the best height increment was from *C. junghuhniana*, which reached 69 cm after a year, with 95 per cent survivors; and at Dapcha (1600 m) at 16 months the best was *C. littoralis* with 67 per cent survivors and a mean height of 64 cm. Unless later height growth accelerates these growth rates are unimpressive, and do not suggest that casuarinas have a great future in Nepal.

Casuarinas form a symbiotic association with species of *Frankia*, an actinomycete which causes nodules to form on the roots, which fix nitrogen. It is possible that the absence of *Frankia* is partly responsible for the poor results so far obtained in Nepal, and if further trials were to be made inoculation with *Frankia* would be desirable.

Seeds of casuarinas are small, with between 200,000 and 3 million seeds kg⁻¹. The dried seed of most species can be stored in sealed containers for long periods, without loss of viability. The seed should be sown in trays, using techniques for small-seeded species, and the seedlings pricked out into poly-pots. In the Terai about four months in the nursery should be adequate for most species, as far as is known.

References: National Research Council (1984); Troup (1921).

Cedrela serrata see *Toona serrata*.

Cedrela toona see *Toona ciliata*.

Cedrus Trew

Pinaceae

Cedar

***Cedrus deodara* (Roxb. ex D. Don) G. Don**

Nepali: devdara, dewar.

Deodar.

Large evergreen tree. Needles 2.5–4 cm long, in dense clusters at the ends of short shoots. Cones erect, barrel-shaped, 10–13 cm long, brown when ripe.

Natural occurrence

It occurs naturally in Nepal only in the west, in the basin of the Karnali River, with some scattered trees in the Thuli Bheri valley, its easternmost limit; it grows between 1900 and 2600 m, usually on northwest- and northeast-facing slopes. It is commonly planted in the west, especially near temples, and was planted in the Kathmandu Valley before 1820 (K. Shrestha, 1984). In the Karnali basin it may once have been commoner than it is at present as in the past large numbers were felled and floated down the rivers to India.

Silvicultural characteristics

It is capable of growing to a great size, up to more than 70 m in height by 4 m in diameter. It is a light-demander, but young seedlings are very subject to being dried out by strong heat and so benefit from side shade. It grows on a variety of soils, but avoids stiff, badly drained soils; on shallow rocky soils its growth is stunted. Young seedlings do not suffer greatly from frost, except in frost hollows. Both seedlings and mature trees are very sensitive to fire, and the seedlings are liable to damage by browsing.

Natural regeneration

The cones break up on the tree and release the winged seed between October and December. About one year in three is a good seed year. Most of the seed falls close to the parent trees, and lies on the ground over winter; if conditions are favourable it will germinate in March or April to produce dense masses of young seedlings. Seedling establishment is best on newly exposed mineral soil; it is very much impeded by accumulations of undecomposed needles. Raking away such needles is one way to stimulate regeneration. The survival of the seedlings during the first year is strongly influenced by the monsoon, and a good early monsoon is particularly important. Full light is advantageous except

sites ranging from the Terai to 1600 m: *C. cunninghamiana* Miq.; *C. equisetifolia* L.; *C. glauca* Sieb. ex Spreng.; *C. junghuhniana* Miq.; *C. littoralis* Salisb. (*Allocasuarina littoralis* (Salisb.) L. Johnson); *C. torulosa* Ait. (*Allocasuarina torulosa* (Ait.) L. Johnson).

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when light shade is needed to prevent desiccation, but even under light shade growth will be reduced.

Artificial regeneration

Seed

On average about one year in three is a good seed year. The female cones are formed in August and continue to develop for a year or a little longer; in May they are clearly visible on the trees, and so it can be judged whether the year is likely to be a good seed year or not. They ripen in September or October, when they turn brown. They should be collected before they begin to break up and release the seeds. The seed can be extracted by drying the cones, as for pines. There are about 8000 seeds kg^{-1} and the number of seeds per cone ranges from about 50 to over 200. The seed, which is oily, loses its viability within about four months, so it is probably better to sow the seeds immediately after collection, although at higher altitudes they will not germinate until the beginning of the warmer weather.

Nursery and plantation techniques

The seed should be sown directly into polypots, with two seeds per pot; alternatively it may be sown in beds or trays, and the seedlings pricked out into pots when they are 2–4 cm tall. The seed beds need to be protected against rodents. In cool areas the seed germinates best without shade, but in hotter areas germinating seedlings and newly pricked-out seedlings may need shade. In most localities it will probably be necessary to keep the seedlings for about 20 months in the nursery. In Jumla bare-root plants are used, after 12 months in the seed bed, or they are transplanted for a further 12 months and eventually planted out when two years old (Bruce, 1985).

In India direct sowing has been used, but usually in areas with a regular winter snowfall, when the seed is sown just before the snow is expected. Such conditions are very rare in Nepal. Even in areas of winter snowfall, the monsoon is the best time for planting out nursery-raised stock.

Performance in plantations and rate of growth

There is not a great deal of experience in Nepal. At Kharidunga (2400 m) 4.5 years after planting there were 75 per cent survivors with a mean height of 44 cm, and the plants were tending to stagnate; however this is a poor site. In India Troup (1921) quotes average growth for plantations as 2.7 m in height by 5 cm in diameter after 15 years, but a good plantation reached 7.5 m in height by 20 cm in diameter in 17 years. Yield tables for natural forest give, for Quality I, a height of 9.4 m by a diameter of 19.5 cm at the age of 20, with a mean annual

increment of $5.8 \text{ m}^3 \text{ ha}^{-1}$; this is on a 'D' grade thinning regime (Champion and Mahendra, 1933).

Uses

It is a very valuable timber, which is very strong for its weight and durable. It is the most important timber in the western Himalaya of India, used for construction, general carpentry, railway sleepers and many other purposes. It weighs about 560 kg m^{-3} . Wood, resin and bark have numerous medicinal uses.

Importance in Nepal

It has not been planted to any large extent, except for religious reasons near temples. A few trees can be seen in the Kathmandu Valley, at considerably lower altitudes than those of its natural occurrence, and appear to be growing quite well there. As it is primarily a timber tree, and not very fast-growing, its use in communal forestry plantations is rather limited.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Indian Timbers (1976); Lamichhaney and Joshi (1980); Suri and Seth (1959); Trotter (1958); Troup (1921).

Ceiba Mill.

Bombacaceae

Ceiba pentandra (L.) Gaertn.

(Syn. *Eriodendron anfractuosum* DC.)

Large deciduous tree with horizontal branches. Stems often with stout conical prickles. Leaves digitately divided into 5–8 leaflets. Flowers creamy white, 4–5 cm across. Fruit a hanging capsule, filled with floss enveloping the seeds. Widely distributed and naturalized in tropical countries, probably originally from South America. It is mainly valued for kapok, the floss surrounding the seeds, which is superior to that of *Bombax*. It has been tried out on a small scale in the Terai; at Butwal (140 m) from trees 2.5 years old there were 100 per cent survivors with a mean height of 6.3 m and dbh 5.8 cm. It is not suitable for higher altitudes. The fruits ripen between March and May. There are about 16,000 seeds kg^{-1} . Nursery treatment is the same as for *Bombax*. It can also be propagated from large cuttings, 1.5–2 m long. For kapok production spacing in plantations should be wide, 6 m x 6 m, or more. Taungya crops can be grown between the trees.

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References: H.B. Joshi (1980); Purseglove (1968).

Celtis L.

Ulmaceae

Trees or shrubs. Leaves with three strong veins from base. Flowers small, without petals. Fruit a drupe.

Key to species

- (1) Leaves deciduous. Fruits one or two together in the leaf axils 2
- (1) Leaves evergreen. Fruit in branched clusters. Confined to eastern Nepal, below 1400 m
C. timorensis Spanoghe (syn. *C. cinnamomea* Planch. Not dealt with further.)
- (2) Teeth on margin of leaf covering three quarters or more of the distance between the apex and the base; teeth ending in a sharp point; upper surface of leaf covered with hairs which eventually break off to leave a rough sandpapery surface *C. australis*
- (2) Teeth on margin of leaf usually absent from lower half; apex of teeth bluntly angular; hairs confined to veins on under side of leaf *C. tetrandra* Roxb.

Celtis australis and *C. tetrandra* are very closely related and there is some doubt whether they are in fact distinct species. In the Enumeration all definitely identified specimens have been called *C. tetrandra*, and it is possible that most Nepalese khari are this species. As the two species have not been distinguished in the field, and are likely to be similar in their silvicultural characteristics, they are considered together here as *C. australis* in a broad sense.

Celtis australis L.

Nepali: khari.

Natural occurrence

It grows at altitudes of between 700 and 2400 m in all regions of Nepal. At its lower limits it is often found in moist situations near rivers. Between 1000 and 1500 m it is often cultivated near villages for fodder. Outside Nepal it extends westward to southern Europe.

Silvicultural characteristics

It is a medium-sized deciduous tree which will withstand a moderate amount of shade. It grows on a variety of soils, but will not withstand impeded drainage; on dry gravelly shallow soils its growth is stunted. The seedlings are fairly frost-hardy, though frost may cause premature leaf fall. They are killed by prolonged drought. The tree has a thin bark and so is killed by even light fires. It coppices and pollards well. The seeds are dispersed by birds.

Artificial regeneration

Seed

The seed ripens in October to December; when ready for collection the fruits are dry and black. The seed is variable in size, and numbers per kilogram ranging from 4500 to 11,000 or more have been recorded. It can be stored in sealed containers.

It is often difficult to germinate the seed. When untreated it may take over 50 days and then only give 2–6 per cent germination. Experiments on germination were made by Burslem (1989d). He found no germination within 40 days from untreated seed, or seed treated with hot water; 9 per cent from cold-stratified seed; and 76 per cent from excised embryos. Embryo excision is not a practical technique for routine nursery work, but cold moist stratification gives some germination, though rather low. The technique was used at Chalnakhel nursery in 1987 when seed collected in October was mixed with twice its volume of moist sand and stored in a pit about 1 m deep for 92 days between December and March. This seed had a germination percentage of about 21. Further trials should be made of methods of mechanical or chemical scarification. It should be noted that in Ilam District no problems with seed dormancy were reported (Mader and Stewart, 1983). However this discrepancy may be due to confusion with other species of *Celtis*.

Nursery and plantation techniques

Stratified seed should be sown in beds or trays in February to March, under shade, and the seedlings pricked out into polypots after three or four weeks. In nurseries below 1500 m it should be possible to produce plantable stock in 4–5 months. The seedlings are very sensitive to drought and should be kept well watered. *Celtis* species are propagated by cuttings and layering in Europe and North America.

Performance in plantations and rate of growth

Most available records are from trials at above 1700 m, and in these initial growth has been slow: 50–60 cm after two years. Above about 2300 m trials

have failed. Better results could be expected at lower altitudes. In India naturally growing trees have a diameter increment of about 6 mm a year.

Uses

The main value of *Celtis* is for fodder, and in some places, for instance parts of Jumla District, it is the most important fodder tree (B.D. Yadav, 1992). It is also an important fodder in Dhankuta District, eastern Nepal, and presumably in other places where the tree is plentiful. It is fed especially in the period between April and June, from the new flush of leaves, and again from October to mid-January; in some places it is also quite an important fodder during the monsoon. The leaves have a crude protein content of about 15 per cent, of which the digestibility coefficient ranges from 63 per cent in May to 43 per cent in October (R.V. Singh, 1982). According to D. Bajracharya *et al.* (1985) the crude protein content is about 9 per cent. The wood is tough and strong and is used for ploughs and tool handles; it weighs about 720 kg m⁻³ and is a very good fuelwood. The fruit is used medicinally.

Importance in Nepal

Its main value is as a fodder tree for farmers to plant on their own land, though survival rates in private planting have been rather low (39 per cent according to J.G. Campbell and Bhattarai, 1983b). In plantations it is very liable to browsing damage.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Mader and Stewart (1983); R.V. Singh (1982); Streets (1962); Troup (1921).

Ceratonia siliqua L.

Caesalpiniaceae

This tree from the Mediterranean region produces pods which are a very valuable fodder. It has been tried on several occasions in Nepal, but has always failed. It is a good example of species from areas of winter rainfall failing to thrive under tropical summer rainfall conditions.

***Choerospondias* B.L. Burtt and A.W. Hill**

Anacardiaceae

***Choerospondias axillaris* (Roxb.) B.L. Burtt and A.W. Hill**

(Syn. *Spondias axillaris* Roxb.)

Nepali: lapsi.

Medium to large deciduous tree. Leaves alternate, odd-pinnate, with 6–8 pairs of ovate lanceolate leaflets 8–12 cm long, ending in long points; margins serrate in young trees, without teeth in older. Flowers greenish-white, about 6 mm in diameter, in panicles. Fruit ovoid, 2.5–3 cm long, yellow when ripe.

Natural occurrence

In Nepal it grows between 950 and 1900 m, though its natural range is uncertain as it has been widely planted for its fruit. Outside Nepal it is found in Sikkim and Assam, and extends to Thailand, south China and Japan.

Silvicultural characteristics

A light-demander. It has intermediate tolerance to soils of low fertility, and to dry soils. Although the seedlings may be damaged by frost, its survival in trials up to about 2200 m has been quite good, though growth at these altitudes is slow. It coppices well. It does not produce fruit if planted below 950 m, though the tree will grow.

Artificial regeneration

Seed

The fruit ripens between October and January. It contains a single hard stone, in which there are up to five seeds. The stones can sometimes be obtained in the local market from sweetmeat makers, but care should be taken that they have not been cooked. There are about 300 stones kg⁻¹; large stones are preferable to small stones, which give poorer germination. It is not necessary to extract the seeds from the stones, which can be stored whole in sealed plastic bags, after removing the flesh and drying them thoroughly. Seeds stored in this way will retain their viability for about a year.

Nursery and plantation techniques

The stones are sown whole in trays or beds, after the pulp has been removed if fresh stones are used. They should be sown on their sides, spaced at 5 cm x 5 cm, and protected against rodents by wire mesh. Germination is very variable. It usually begins 3–4 weeks after sowing, and may continue for two or more

months. It has been reported that treating the stones with hot water accelerates germination but this needs confirmation. Cracking the stones with a hammer before sowing them might also be tried.

The date of sowing is also important. Particularly at higher altitudes seed sown in December rarely germinates before late February, so sowing before February or March is pointless. At lower altitude nurseries the stones should be sown in late February; above 1500 m, in August. Germination percentages are usually fairly satisfactory; the average number of plants raised from 1 kg of stones in community nurseries has been about 300, but the better nurseries have produced more than 400.

Each stone will produce up to five seedlings. These should be pricked out about two weeks after germination, when they are 4–5 cm high into 3 inch x 7 inch (7.5 cm x 18 cm) or 4 inch x 7 inch (10 cm x 18 cm) polypots containing a mixture of soil and sand; compost is unnecessary. The seedlings should be shaded for a few days after having been pricked out, but after they have recovered from transplanting the shade should be removed, otherwise the seedlings will be weak and spindly.

Root pruning of seedlings from February sowings will be necessary from April and May onwards and should be repeated every 3–4 weeks. In May the seedlings should be spaced out. Below 1500 m stock suitable for planting, 20–30 cm tall, can be produced in about five months; above this altitude about 11 months will be needed. If the seedlings are kept in the nursery over winter protection against frost is necessary. The use of hardwood stem cuttings has been suggested, but up to date such cuttings have produced buds or shoots, but no roots. In plantations the spacing should be wide, at least 5 m x 5 m, to allow good crown development for fruit production. To obtain satisfactory growth thorough weeding is necessary.

Performance in plantations and growth rates

On good fertile soil its growth can be rapid, averaging about 1 m in height per year, but in general its growth is much slower. One of the best results in trials was from Kadamba (1500 m) where trees 28 months old had 80 per cent survival and a mean height of 101 cm. On average, about 60 cm in height after two years, and 90 cm in three years, can be expected.

Uses

Its main value is for its fruit, which is eaten both fresh and made into a variety of sweetmeats and chutney. Its timber is soft and light, weighing 400 kg m⁻³, and so is a very inferior fuel. It is also used as fodder, but not on a very large scale.

Importance in Nepal

In some places farmers like it for planting as a fruit tree, but elsewhere, for instance Lumle, it is not very popular. Although it has been planted in community forestry plantations, planting by individuals, who would be more likely to tend it properly, would seem to be more promising. However survival of trees planted by farmers has varied from moderately good to poor. It is only worth planting on fertile soils.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989).

Cinnamomum Schaeffer

Lauraceae

***Cinnamomum camphora* (L.) J. Presl**

Nepali: kapur.

Evergreen tree. Branches blackish and hairy. Buds enclosed in overlapping scales. Leaves alternate, 5–12 cm long, on long stalks, ovate-elliptic, apex long-pointed; shining above, whitish below; distinct midrib, with 2–3 pairs of secondary nerves; smelling strongly of camphor. Flowers yellow, in clusters shorter than the leaves. Fruit a berry 6–10 mm across, blackish when ripe.

Occurrence

Native of China, Japan and Taiwan but fairly widely planted in Nepal up to about 2000 m.

Silvicultural characteristics

Its best growth is on moist, deep sandy loams, such as alluvial soil near streams. It will grow on less fertile soils, but then its rate of growth is much slower. It has some tolerance to frost, and in the United States will grow where the temperature does not fall below -9°C , but in England will only survive in the mildest localities. The tree coppices well. It is browsed, but not severely. It will tolerate some degree of neglect, and survived well at Pipal Chaur, in the Kathmandu Valley, eight years after being planted in 1979, though many other species had disappeared (H.B. Thapa and Budathoki, 1987).

Artificial regeneration

Seed

The fruit ripens between September and November, when it turns black. There are about 3500 seeds kg^{-1} . The seed is oily, and retains its viability for a few months only. After the pulp has been removed from the fruit, the seeds should be sown immediately, in beds or trays. The germination tends to be low and often takes a very long time; Ghosh (1977) gives a figure of between 200 and 359 days, and Burslem (1989c) found that germination of seed sown in November began in 15–16 weeks, and took 200 days to complete, the final germination rate being only two per cent. This agrees fairly well with results from Simlang nursery (1585 m) where seed sown at the end of November germinated in early April.

Burslem tried to break the seed dormancy by manual scarification and treatment with hydrogen peroxide. The latter failed completely. Scarification, by cutting and removing part of the seed coat, near to where the stalk is attached, caused germination to begin in 10 days; after 25 days it reached 18 per cent, but about 70 per cent of the seedlings were abnormal, due to damage to the embryos in the scarification process. For the time being it looks as if low and delayed germination will have to be accepted in Nepal.

Nursery and plantation techniques

The seed should be sown in shaded beds and the seedlings pricked out into polypots when they are 2–4 cm high. Seed sown in October to November will produce plants 30–40 cm tall in the second monsoon after it has been sown, that is **after** about 20 months in the nursery. Stumps have also been used successfully. In the U.S.A. and Europe *Cinnamomum* species are propagated from cuttings of half-ripened wood in spring.

Performance in plantation and growth rates

Growth is fast on suitable localities. At Banepa, east of Bhaktapur (1450 m) the base of the second log of a felled tree was about 45 cm in diameter (the butt log had been removed). This tree was said to be about 20 years old, and was growing near a stream. Nearby on higher ground a tree about 14 years old had a trunk less than 15 cm in diameter. However on poorer sites growth may be much slower. At Pipal Chaur (1350 m) eight-year-old trees averaged only 1.5 m in height, though they had been lightly browsed. At Dehra Dun 17-years-old trees averaged about 14 cm in diameter.

Uses

The tree is the source of camphor used in pharmacy, etc., but much of the world's supply is now produced synthetically from pine resin or coal tar. In

Nepal it is not used to produce camphor but is mainly planted in gardens and at the entrances of houses for religious reasons, and as an ornamental tree, though the wood fetches a very high price when it is available. The wood is greyish-white and moderately hard, and weighs about 600 kg m^{-3} . In Nepal, however, it is not much used for timber, but is used in cremations and burnt as incense.

Importance in Nepal

For camphor production, which is mainly from the leaves and twigs, the trees are trimmed to a bush or hedge when they are about five years old, and kept in this shape by trimming. In Sri Lanka the average annual yield of distillate is about 140 kg ha^{-1} .

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Macmillan (1956); Streets (1962); Troup (1921).

Cinnamomum glaucescens (Nees) Drury

(Syn. *C. cecidodaphne* Meisner)

Nepali: sugandha kokila, malayagiri.

Evergreen tree; buds enclosed in overlapping scales. Leaves alternate, 7–10 cm long, on stalks 1–2 cm long, elliptic, with well-marked midrib and 4–5 pairs of lateral veins. Inflorescences covered in brown hairs. Fruit about 3 cm long, base enclosed in a cup 10–12 mm across.

Occurrence

Recorded in Nepal from the Rapti zone between 600 and 1360 m; also reported from eastern Nepal. Outside Nepal it grows in Sikkim, Bhutan, Manipur and the Khasi Hills.

Artificial regeneration

Seed

The seed ripens from late October to late November; there are about 2000 seeds kg^{-1} . They lose all their viability within two months, and should be sown as soon as possible after collection, after removing the flesh, washing the seeds in water, and drying them in the sun. At Godavari the seed was sown in December in drills 5 cm apart, in beds covered with polythene sheeting, made airtight by embedding the edges of the sheeting in soil. Under the polythene the maximum temperature was 35°C , and the minimum 10°C . Germination began after 30 days, and was just over 30 per cent. In the next year seed sown on 6 December

using similar methods gave 48 per cent germination; this fell to 16 per cent for seed sown on 4 January, and to nil for later sowings.

Performance in plantation and growth rate

Seedlings from these sowings had an average height of about 3 m after two years at Hetauda, but only about 1 m at Godavari. The tree coppices well.

Uses

The pericarp of the fruits is distilled to yield about four per cent of an essential oil used in perfumery. After distillation the residue is used for joss-sticks, but it contains about 35 per cent of fixed oil which could be extracted by solvent or pressing. The oil is also used in ayurvedic medicine.

References: Natural Products Industries (n.d.) Bulletin No 27 (the illustration there is not of *C. glaucescens*); Roy and Raj Bhandary (1989) (on which this account is mainly based); Troup (1921).

***Cinnamomum tamala* (Buch.-Ham.) Nees and Eberm.**

Nepali: dalcini (bark); tejpat (leaf).

Gurung : pingc.

Leaves opposite, with three veins running from the base to the apex, 10–15 cm long, lanceolate to ovate-lanceolate, with short blunt points; flowers in panicles 5–10 cm long; fruit about 1 cm across, in a shortly lobed cup. Found in Nepal between 500 and 2000 m. Fruit ripens June to October. The tree is known as Indian Cassia-lignea; the bark and leaves are used for flavouring, and medicinally. The bark is sometimes used as a substitute for true cinnamon, *C. zeylanicum* Breyn, which does not grow in Nepal. Sometimes the two species are confused, as they have the same Nepali name, but records of *C. zeylanicum* from Nepal refer to *C. tamala* or some related species. True cinnamon grows under an average temperature of 29°C and a well-distributed rainfall of 2000–2500 mm, and is unlikely to thrive in Nepal.

Reference: Hausler (1988).

Cordia L.

Cordiaceae

Cordia dichotoma Forster

(Syn. *C. myxa* auct. non L.)

Nepali: bohori.

Deciduous tree. Leaves alternate, with 3–5 basal veins, elliptic-lanceolate to broadly ovate, 7–15 cm long, stalk 2.5–5 cm, without hairs but rough to feel. Flowers small, white, in large loose inflorescences. Fruit 1.2–2.5 cm long, fleshy, in a cup formed from the persistent calyx.

Natural occurrence

Recorded from altitudes from 200 to 1500 m, but may go higher. Outside Nepal it has a very wide range, from the dry forests of Sind and Rajasthan, to tidal forests in Burma, and to the Himalaya, under rainfalls ranging from 250 to more than 3000 mm yr⁻¹. It has often been planted.

Silvicultural characteristics

A small to moderate-sized deciduous tree which tends to be crooked. It is a moderate shade-bearer. It grows best on deep moist sandy loams, and is not suited to shallow, gravelly or dry soils. Young seedlings are killed by severe frosts, and also suffer if exposed to hot sun. They are damaged by browsing and fire, but have good power of recovery from these injuries. The tree coppices and pollards well.

Natural regeneration

The seeds are dispersed by birds and monkeys. In India the fruit ripens, and the seeds germinate, during the monsoon; young seedlings can frequently be found during the rainy season, but unless they are in moist and shady situations many die off in the subsequent dry season.

Artificial regeneration

The fruit ripens from June to September in northern India, but in Nepal the dates recorded are from late August to December, though the latter date may be doubtful. The fruit is yellow, turning black as it ripens. Each fruit contains a single stone which may contain one or two, occasionally up to four seeds. There are between 5000 and 8500 stones kg⁻¹. Up to 5000 seedlings have been raised from 1 kg of stones. The stones can be stored for a year or more in sealed

containers, after the flesh has been removed from them and they have been dried.

Germination begins in about four weeks, and may continue for up to a further eight weeks, but much depends upon the temperature. As the germination period tends to be prolonged, and more than one seedling may emerge from a single stone, it is better to sow the stones in beds and prick out the germinating seedlings into plastic pots when they are about 2 cm tall. At Chalnakhel nursery (1370 m) where seed was sown in November, the seedlings from early germinating seed were 25–30 cm tall by the monsoon, and from later germinating seed 7–15 cm. At Dobaghat (1250 m) it was reported that seed sown in January which germinated in March produced plants 25 cm tall by the onset of the monsoon. Thus for lower altitude nurseries sowing in February–March would appear to be the best time, and at higher altitudes sowing in September–October.

During hot weather the seedlings should be shaded while they are small. In a nursery at 1900 m about 90 per cent of the nursery seedlings were destroyed by frost, which indicates that this is above the desirable altitude for raising *C. dichotoma*. The use of stumps would be worth a trial (Troup, 1921). Farmers in Dhading say that it can be propagated from stem cuttings (Upadhyay, 1991).

In a trial at Tistung, an exposed site about 1900 m, survival of unfertilized seedlings was 100 per cent when the trees were planted under the shade of pines, but nil when they were planted in the open. In this trial there was no positive response to artificial fertilizer (Complexol, 20:20:0). However in a trial at Melechaur, where the seedlings were also planted under pine shade, 28-month-old trees averaged 15 cm in height unfertilized, and 32 cm when fertilized with 50 g Complexol per tree.

Performance in plantations and growth rates

At higher altitudes early growth is slow, as shown by the data given above. In India in natural forests ring counts show a mean annual diameter increment of between 6 and 17 mm. Coppice regrowth is relatively fast; at Dehra Dun shoots 10 years old reached a mean height of 6 m and a diameter of 19 cm.

Uses

The leaves are a good fodder, with a crude protein content of 12–15 per cent, which has a digestibility coefficient of about 70 per cent. Total digestive nutrients are about 27 per cent of the dry weight of the leaves. Leaf fall is in February–March (Falgun–Chaitra) and the new foliage appears in the pre-monsoon period. The wood is soft, but fairly strong; it is readily attacked by insects. It weighs about 500 kg m⁻³. Its calorific value is about 26,000 kJ kg⁻¹; it burns

rather quickly and the smoke is somewhat irritating to the eyes (Chaturvedi *et al.*, 1986). An oil is obtained from the fruit pulp and the kernels are also edible. The fruit also has medicinal uses. A bast fibre from the branches is used for ropes.

Importance in Nepal

Cordia dichotoma is a good fodder, but in general is only used on a small scale, perhaps because it is not very abundant. It has been planted by farmers, but again on a small scale.

References: Gamble (1922); Panday (1982); R.V. Singh (1982); Troup (1921).

Cordia grandis Roxb. has larger leaves, 12–20 cm long, with small white raised spots on the upper surface and fruit usually less than 1 cm in diameter. It is confined to eastern Nepal, at an altitude of about 500 m.

Cordia alliodora (Ruiz and Pav.) Cham. from Central America has been tried at Chitripani and Adabhar, but has failed.

***Cryptomeria* D. Don**

Taxodiaceae

***Cryptomeria japonica* (L.f.) D. Don**

Nepali: dhupi salla.

Large evergreen tree. Leaves pointed, curved inwards, 7–12 mm long, densely surrounding the branchlets. Cones about 1.4 cm in diameter at the ends of short branchlets, almost spherical, consisting of 20–30 woody scales which are toothed at the apex.

Natural occurrence

A native of Japan, which was introduced to India, in particular the Darjeeling area, in about 1840; from there its cultivation has spread to Nepal, particularly the far east of the country.

Silvicultural characteristics

It grows best in areas of heavy rainfall, between 1500 and 2000 m, and prefers deep fertile soil. In one plantation in Ilam District it was planted at 1350 m on a good black sandy soil, with some shade from *Schima* coppice, and here it did

well, but it should not be planted on hot, dry sites. It will withstand frost—it is hardy in most parts of Britain—but young seedlings in the nursery should be protected against it. Near Pakhribas at 1933 m, survival was 80 per cent, though about 15 per cent of the survivors had dead tops. In the same trial only 30 per cent of *Alnus*, and 30 per cent of *Schima* survived. According to Troup cattle do not eat the young plants, but in Ilam considerable damage has been done by hares.

Artificial regeneration

The seed ripens between October and December; the cones are collected from the trees and dried in the sun to release the seeds, as is done with pines. There are between 250,000 and 300,000 seeds kg^{-1} ; 1650 cones weigh 1 kg, and 1 kg of cones yields about 80 g of seed. The seed can be stored for up to two years if dried and kept in sealed containers, but loses its viability within a few months if stored in cloth bags. Fresh seed has a germination percentage of up to 80, and germination takes 2–4 weeks, if the seeds are sown after the end of the cold weather.

The seed is sown in beds or trays and the seedlings pricked out when about 2–3 cm tall; the seedlings benefit from shade when they are young, but it should be removed gradually 4–6 weeks after the seedlings have been pricked out. Sowing seed directly into polypots should also be tried. Seedlings raised in polypots in Ilam from seed sown at the end of March 1981, averaged 23 cm in height by mid-July 1982; this indicates that about 15 months in the nursery are needed.

In Ilam, *Cryptomeria* has also been raised successfully from bare-root seedlings, and from seed sown directly into beds, without any transplanting. In a supervised trial, plantation survival of bare-root plants after one year was 94 per cent, compared with 98 per cent for polypot-raised seedlings. However in private plantings survival of bare-root plants was only 51 per cent, as compared with 77 per cent for polypot-raised seedlings (Olsson, 1983). These figures indicate that bare-root plants can be used successfully in the cool, humid conditions of Ilam District, provided that planting is well supervised. *Cryptomeria* can also be raised from branch cuttings, but these take several months to root (P.M. Amatya, 1982).

Rate of growth

Initial growth in the plantations is rather slow, seedlings taking a year to reach a height of about 35 cm. Thereafter, however, growth is very fast on good sites. In Darjeeling trees 22 years old averaged 29 cm in diameter by 19 m tall, with an annual volume increment of about $21 \text{ m}^3 \text{ ha}^{-1}$ (Troup, 1921).

Uses

It is mainly grown for its timber which is strong, durable, and easy to work, and is used in general construction. However, timber from very fast-growing trees is reputed to be inferior, and for this reason it is recommended that in India it is only grown above 2000 m, and in dense plantations, to provide denser timber (Suri and Seth, 1959). It weighs about 340 kg m⁻³.

Importance in Nepal

In Ilam it is a popular tree both for community forestry plantations, and for private planting by farmers. It has also been planted by farmers elsewhere, for instance in Lalitpur District (Hausler, 1990), but here survival was very variable, from 7 to 66 per cent, and poor compared with that of most other species. It is best suited for areas of high rainfall, and for planting on deep soils.

Note: The Nepalese name dhupi literally refers to any tree producing incense, and is applied to many *Cupressus* and *Juniperus* species, in addition to *Cryptomeria*. Thus in reports from nurseries in which only the Nepalese name is given, it is often uncertain what species is meant.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lahiri (1975); Lamichhane and Joshi (1980); Olsson (1983); Suri and Seth (1959); Troup (1921); Webb *et al.* (1984).

Cupressus L.

Cupressaceae

Cypress

Cupressus torulosa D. Don.

Nepali: agar dhupi, dhupi, raj salla.

Evergreen tree. Leaves on branchlets scale-like, four-ranked, closely appressed, bluntly pointed. Cones about 1 cm in diameter, spherical, each scale with a minute downwardly pointing prickle.

Natural occurrence

In Nepal it is found between 1800 and 3500 m, in the west, its eastern limit being the Kali Gandaki valley. It occurs in association with *Cedrus deodara* and *Pinus wallichiana*, and is often dominant on very steep limestone slopes. It

is one of the most drought-tolerant tree species in Nepal, occurring almost as far north as Jomsom, in Mustang, and on north and west slopes east of that town; in this region the rainfall is 300 mm or less.

Silvicultural characteristics

A moderate light-demander. Although it is very frequently found on limestone it will tolerate other types of soil, and in addition is drought-tolerant, though its growth on poor, dry soils will naturally be less than on deeper, more fertile soils. It can be planted at considerably lower altitudes than those at which it occurs naturally, and has grown well, for instance, at Dehra Dun in India. It tolerates frost.

Natural regeneration

The cones open on the trees and shed their seed between August and December; the seeds are winged and distributed by wind. In nature germination does not begin until the next monsoon. Seedlings establish themselves most easily on exposed bare soil such as on landslips and abandoned fields; sometimes they are found in rock crevices.

Artificial regeneration

In India the seeds are ripe within the cones from April onwards, though the cones do not begin to open and shed their seeds until August; they continue to shed seed until November or December. In India, June is considered the best time for seed collection, but obviously there is a considerable period during which collection would be possible. Closed cones collected in Tansen in June produced abundant mature seeds. The seeds are extracted by drying the cones in the sun, like those of pines. There are from 170,000 to 250,000 seeds kg⁻¹. They can be stored in sealed containers for 18 months.

The seed is sown in shaded beds and the seedlings pricked out into polypots when they are about 2 cm tall. Germination is sporadic and may be delayed several months. According to M.W. Campbell (1983a) the seedlings grow well under cooler conditions, but those which germinate towards the beginning of the hot weather remain stunted and are slow to grow. The seedlings are likely to need about 15 months in the nursery.

Performance in plantations and growth rates

Available trial records are all from over 2000 m; for the first two or three years growth is slow, the mean height at two years being 40 cm or less. Thereafter growth rates increase somewhat. A trial 4.3 years old at Kharidunga (2500 m) had only 38 per cent survivors, but the mean height was 90 cm and the annual

rate of height increment increasing. Although these trials are well within the natural altitude range of the species, experience in other countries shows higher rates of growth at lower altitudes, for instance at Dehra Dun (670 m) trees 12 years old reached 22 cm in diameter.

Uses

The timber is of high quality and is very durable; it is used for building, especially for temples in India. It is also burnt as incense. It weighs about 600 kg m⁻³.

Importance in Nepal

It has not been planted to a great extent except for ornament, though there is a good pole-sized plantation near Tansen. However its excellent form, good timber qualities, and tolerance of a range of sites suggest that it should be tried on a wider scale.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Suri and Seth (1959); Troup (1921); Webb *et al.* (1984).

Cupressus corneyana Hort. ex Carriere

(Syn. *C. cashmeriana* Royle ex Carriere, *C. funebris* auct. non Endl.)

Very closely related to *C. torulosa* and sometimes considered to be a variety of it. The branches are pendulous and the cone scales are flat or with a blunt peg at their centre. It also somewhat resembles the Chinese weeping cypress, *C. funebris*, and has been confused with it, but is now considered to be distinct. It is endemic to Bhutan, but has been widely planted, especially near temples. Despite its synonym, it is not indigenous in Kashmir. It was introduced long ago to Nepal; it is the *Cupressus* with long pendulous branchlets commonly planted in Kathmandu. There are some large trees near Kakani. As *C. cashmeriana* it has been successfully planted in West Bengal, between 1000 and 2000 m, where on good sites it has given a mean annual increment of 21–28 m³ ha⁻¹ (Ghosh, 1977). As it grows vigorously around Kathmandu it would be worth wider trials in Nepal. Its silviculture is similar to that of *C. torulosa*. There are about 290,000 seeds kg⁻¹.

Reference: Lahiri (1975).

***Cupressus lusitanica* Mill.**

Leaves with spreading free-pointed tips. Cones globular, 1.5 cm in diameter, with a hooked spine at the centre of each scale. A Mexican species which has been widely planted in mountainous areas in the tropics. It has been tried in a few places in Nepal; at Tistung (1800 m) there is quite a vigorous stand planted in 1982, though the rate of growth there is much slower than that of pines, especially *P. patula*. In the Nepal–Australia Forestry Project trials at Pharping it averaged 1.1 m high when 2.5 years old, though survival was good. There are 170,000 to 320,000 seeds kg⁻¹; it grows faster in the nursery than *C. torulosa* and plantable seedlings should be obtainable in nine months.

***Cupressus arizonica* Greene**

Introduced into Nepal, but no survivors known.

***Cupressus macrocarpa* Hartw.**

Leaves with short, blunt tips, smelling of lemon verbena; cone 3 cm in diameter. Introduced to Nepal; specimens in the Pinetum, at the Royal Botanic Garden, Godavari. Unlikely to be of great interest; grows under similar conditions to *C. lusitanica*.

***Cupressus sempervirens* L.**

Leaves blunt at tips, unscented or faintly smelling of india rubber. Cones 2.5–3.5 cm in diameter. The common variety, var. *sempervirens* (var. *stricta* Ait.), is fastigiate with a tall and very narrow crown. It has been planted for ornament in Nepal, and there are specimens at Godavari. Native of Mediterranean area.

***Dalbergia* L.f.**

Papilionaceae

Trees shrubs or climbers; leaves odd pinnate, leaflets alternate; flowers small (1 cm), pea-like, white, bluish-white or pink; pods flattened, 1–4 seeded.

Key to Nepal tree species

- (1) Leaflets seven or fewer, generally almost as long as broad 2

- (1) Leaflets nine or more 3
- (2) Leaflets rounded or notched at tip; 2.5–10 cm by 2.5–9 cm; flowers whitish; pod 1–3-seeded, with parallel sides *D. latifolia*
- (2) Leaflets pointed at tip, 2.2–8 cm by 2–6.3 cm; flowers yellowish-white; pod usually 1–2-seeded, narrowed to point at both ends *D. sissoo*
- (3) Leaflets more than twice as long as broad, on stalks 1–3 mm long; 17–23 in number, 1.8–4 cm by 0.8–1.5 cm; flowers pale blue; pods one-seeded, 7–10 cm long; usually a climber, occasionally a small bushy tree; Terai to 1300 m *D. stipulacea* Roxb. (Nepali : tate bari)
- (3) Leaflets less than twice as long as broad, if more then leaf stalks more than 4 m 4
- (4) Branchlets and leaflets clothed with minute grey hairs; leaflets 13–19, 1.7–4 cm by 1–1.2 cm; flowers white or pale mauve; pods 1–3 (–5)-seeded; 700–2000 m *D. sericea* G. Don
- (4) Leaflets hairless, except sometimes for hairs along midrib 5
- (5) Leaflets hairy along midrib below, 1.5–5.5 cm by 0.8–3 cm, each with about 14 pairs of not very prominent secondary veins; flowers bluish-white; pod narrowed at both ends, 1–2-seeded; Terai to 500 m, sometimes planted as a shade tree in tea plantations *D. paniculata* Roxb.
- (5) Leaflets quite hairless, 2.5–5 cm by 1.2–1.7 cm, each with 6–9 pairs of straight, parallel veins; flowers pale pink; pod 1–3 seeded; rare *D. lanceolaria* L.f.

Dalbergia pinnata (Lour.) Prain and *D. volubilis* Roxb. are woody climbers.

Dalbergia latifolia Roxb.

Nepali: sausal.

Trade name: Indian rosewood.

This tree is found in Nepal from the Terai to 1000 m, commonly in *Dalbergia sissoo* forests. Outside Nepal it extends from Kumaon to Indochina, and through much of the Indian peninsula. It is a large deciduous tree, in moist locations almost evergreen, which occasionally reaches over 40 m in height. It is a moderate light-demander. It grows naturally on a variety of soils, and is used in India for afforestation of laterites and degraded soils; under such conditions its growth is likely to be poor, compared with the deep loams which it prefers. Howard (1941) considers it should do well in the Bhabar Terai

provided there is a good layer of loam over the boulders. It does not tolerate poor drainage. It is more frost-tender than *D. sissoo*, and should not be planted in areas where regular frosts occur. Once established it will withstand annual ground fires, but is killed by crown fires. Seedlings are very liable to browsing damage. It coppices well and produces root suckers.

Artificial regeneration

The seed ripens when the pods turn brown between December and April, according to the locality. The pods remain on the trees until the beginning of the monsoon. There are from 18,000 to 37,000 seeds kg^{-1} , the average being about 28,000. There are about 10,000 fruits kg^{-1} each with one to three seeds. It is not necessary to separate the seeds from the pods; the broken pods can be sown. The seed may be stored up to six months in sealed containers, provided it is thoroughly dried first; after six months the germination percentage drops rapidly. The percentage germination of fresh seed ranges from 20 to 80 per cent. Treatment of the seed before it is sown is unnecessary.

Seedlings in polypots can be raised in about three months in the nursery, either by sowing the seed directly into the pots, or by sowing in beds and pricking out later. The seedling has a long taproot, so thorough root pruning is needed. Stumps can also be used very successfully; they should be planted shortly before the break of the monsoon rains. Direct sowing has been used in India, but is now recommended only for very moist and semi-evergreen forest types, as the young seedlings are very susceptible to drought (Ghosh, 1977). Thorough weeding in plantations is essential. Plantations in Tamil Nadu have reached a mean height of 9 m and diameter of 8 cm in ten years, and a height of 11 m by diameter of 15 cm in 18 years (Indian Timbers, 1973b). Other growth data are given by Kadambi (1954).

Uses

Its main use is for its timber, which is one of the rosewoods of commerce and is valued for furniture making in Europe and elsewhere. Indeed it is so valuable a furniture timber that its use for other purposes is deprecated, at least as far as timber from large trees is concerned. Its wood weighs about 820 kg m^{-3} , and has a calorific value, when completely dry, of $21,360 \text{ kJ kg}^{-1}$ and thus should be an excellent fuel if it could be spared for this purpose. The trees are lopped in India for fodder, but it is not primarily a fodder species.

References: Bhargava (1961); M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Indian Timbers (1973b); Kadambi (1954); Lamichhaney and Joshi (1980); Letourneux (1957); Magini and Tulstrup (1955); Rao and Purkay-

astha (1972); Streets (1962); Trotter (1958); Troup (1921). Volume tables are given by Chaturvedi and Mittal (1971) and R.P. Sharma and Jain (1978).

***Dalbergia sissoo* Roxb. ex DC.**

Nepali: sisau.

Sissoo.

One of the most important multipurpose tree species for planting in the Terai and lower elevations of Nepal.

Occurrence

It is characteristic of alluvial soil adjoining rivers, often associated with *Acacia catechu*. In Nepal it grows up to 1500 m. Its general distribution is in the Indus, Ganges and Brahmaputra river systems, including their tributaries, from Afghanistan to Assam. Away from these river systems its range has been greatly extended by planting.

Silvicultural characteristics

It is a large deciduous tree, growing to nearly 30 m on favourable sites; the bole is very often sinuous. Its best growth is found where there is a water table within 8 m of the surface which the roots can reach, including bouldery alluvial soils near rivers. In Nepal it grows well on Bhabar Terai soils provided the water table is high enough. It will however grow on a variety of other soils, but with much poorer growth rates. In India it is planted to reclaim eroded sites, and will grow on soils with high pH (usar soils); saline soils are harmful however. It grows badly on heavy clays, and on soils shallower than about 60 cm. It will withstand inundation, but does not tolerate stagnant waterlogged sites.

It is a strong light-demander, and best development of seedlings is found in full light. The seedlings rapidly develop long taproots, which may reach a length of 1–1.5 m in the first year. In addition to these taproots the tree also develops a wide-spreading superficial root system. Seedlings are particularly sensitive to competition by grass and weeds.

It has some resistance to frost. Seedlings in the cotyledon stage are killed by it, but older seedlings will tolerate mild frost and larger trees are not seriously injured even by severe frost. It is not very fire-resistant; seedlings and pole-sized trees are killed by fierce fires, including fires in tall grass, and even large trees are damaged. Young trees are very liable to damage by browsing. *Dalbergia sissoo* coppices and pollards freely and produces abundant root suckers, especially if the roots have been injured. Its roots nodulate and fix nitrogen.

Natural regeneration

Abundant seed is produced nearly every year. The pods fall complete with seeds between December and March, and lie on the ground until sufficiently moistened by rain or river water to germinate. Dispersal is mainly by flood water, and so in nature *D. sissoo* tends to be mainly found near rivers. Some wind dispersal, however, occurs, and regeneration may also be found on landslips and abandoned cultivation. For the seedlings to establish themselves full light, permeable soils, freedom from weeds, and water within the range of the growing roots, are required. These conditions are found *par excellence* on new sand bars and shingle banks, on which even-aged stands develop. Natural stands may be kept down to dense low bushy growth by grazing. After protection these may recover by regrowth from coppice and root suckers.

Artificial regeneration

Seed

Seed is produced abundantly nearly every year. The pods ripen between December and March; seed should not be collected until the pods have turned brown in colour, and the pods should be collected from the trees, not from the ground. One tree on average produces 1–3 kg of pods. Each pod contains one or two, occasionally three seeds, and there are 13,500–18,000 pods kg⁻¹. One litre of pod segments contains 1600–3000 seeds. About 50,000 cleaned seeds weigh 1 kg. However it is not necessary to extract the seed from the pods, which can be broken into one-seeded segments and the segments sown as they are. The pod segments, after being dried in the sun for several days, can be stored under field conditions for a year in sealed plastic bags, though in the hot conditions of the Terai they may lose about half their viability during this period. For longer storage refrigeration is desirable, provided this is reliable. See Robbins (1988b). The broken pods should be soaked in water for 48 hours before being sown. Germination of soaked seed is usually fairly rapid, between one and three weeks, and 60–80 per cent germination can be expected. Temperatures below 20°C and above 35°C reduce germination (Kumar and Bhatnagar, 1976). One kilogram of pods should produce 3000–6000 seedlings.

Experiments in India using pre-germinated seed have been reported to give good results; the seeds after having been soaked in water are placed in a layer about 15 cm deep, covered with grass or sacking, and well watered. The seeds are picked out and sown as they germinate (Kaushik, 1961). However as normal techniques produce adequate germination it is doubtful how far pre-germination is necessary, except perhaps for sowing seed directly into plastic pots.

Nursery and plantation techniques

Plantations may be established in a number of ways, including use of stumps, plants in polypots, large bare-root transplants, and direct seeding. Planting *D. sissoo* as stumps is the commonest method used. The seed is sown in beds, in lines 10–15 cm apart, with 2–3 full seeds at 15 cm intervals along the lines. After sowing, the seed is covered lightly with soil followed by a mulch of grass or leaves, which is removed about one week after germination begins; if the germinating seedlings show signs of collar rot the mulch should be removed immediately. Sometimes the seed is sown in March or April, in which case the beds will need to be watered until the onset of the monsoon. However at Sagamath, in the Bhabar Terai, sowing during the monsoon was found to be early enough. If a dry spell occurs during the monsoon while the seedlings are still small some emergency watering may be needed, but after the monsoon no further watering is normally necessary. No shading is necessary, but protection against hail may be needed in some localities. One month after germination begins any surplus seedlings should be removed so that the spacing between those left is between 10 and 15 cm. In July or August, if some plants are found to be overtopping the rest, they should be cut back to the same height as most of the plants in the bed. Plants suitable for stumping, averaging about 1 cm in diameter at the root collar, will be ready by the next monsoon. Stumps should have about 2–3 cm stem and 20–25 cm root. After they have been lifted the stumps can be stored up to three weeks, if kept moist and under shade; however planting as soon as the plants have been lifted is preferable. At 50 plants m⁻², 20 m² of bed will be needed for 1000 plants.

To raise plants in polythene pots the seed is sown in beds at the rate of 200 g m⁻² covered in soil and mulch. The seedlings are pricked out into pots just after the first leaves begin to emerge, when they are about 5 cm tall. The seedlings should be shaded for 3–4 days after pricking out. At altitudes below 1000 m they need about 14 weeks in the nursery; i.e. seed sown in the first half of April will produce plantable seedlings by mid-July. At higher altitudes earlier sowing would be necessary, but *D. sissoo* is not very likely to be grown on a large scale above 1000 m. As the seedling develops a strong taproot regular root pruning is necessary. Sowing the seed directly into polypots might be tried, preferably using pre-germinated seed.

Large plants 75–150 cm tall are used in India and might be preferable when small numbers of plants are raised for distribution to farmers. The plants are lifted with balls of earth round their roots, and will take 1–2 years in the nursery. For more details see the section on Nurseries in Volume 1 of this manual.

Dalbergia sissoo can be relatively easily propagated from hardwood cuttings, but it has been found that cuttings from branches of large trees tend to retain their branch character, and do not grow straight upwards. Stem cuttings from lignified young plants are satisfactory. Cuttings 15 cm long, and about 8 mm thick, root readily in the spring. They can be raised by planting them in standard polythene pots, with the base of the cutting about halfway down the pot, to allow space for the roots to develop. Use of such cuttings is important for raising genetically superior plants.

Within the last ten years Dr S.B. Rajbhandary has succeeded in raising *D. sissoo* plants on a large scale by tissue culture (Rajbhandary, 1988). This technique, combined with the use of cuttings, raises interesting possibilities of creating plantations of elite trees on a large scale.

Direct sowing has been widely used in India, generally as line sowings in conjunction with taungya. One kilogram of seed is enough to sow 120–140 m of line, thus at 3 m between the lines about 25 kg will be needed per hectare. Thorough weeding is necessary, and the plants should be thinned out to about 1 m spacing after the end of the first year. Under Nepal conditions the use of plants is likely to be simpler and more satisfactory.

P.T. Evans (1989) gives some interesting results from *D. sissoo* planted by farmers in the Terai. It can be assumed that in most cases, methods used were less than optimum. The following survival rates were recorded.

• Stumps	53%
• Bare-root plants	29.5%
• Polypots, pots removed at the time of planting	38%
• Polypots, pots not removed, but cut open	44%
• Polypots, pots left intact	33%

This indicates that, for farmers, planting stumps is the most foolproof method.

Plantation establishment

Especially in the Terai, *D. sissoo* benefits from thorough weeding. In a trial at Adabhar, although survival was good in all treatments, mean height at 18 months was 3.8 m when the plots were given full cultivation, compared with only 1.3 m when weeding was confined to a circle 50 cm in diameter round the plants. As clean weeding is rarely practicable on a large scale, cultivation of crops between the trees is almost essential for good growth.

At Sagamath the original spacing used was 3 m x 2 m; this was later widened to 4 m x 2 m. Wide spacing is desirable to allow a reasonable period of cultivation of agricultural crops between the trees.

Some trials have been made of very close spacing. The idea was that farmers could plant small areas at close spacing, on a very short rotation, to provide for their domestic fuelwood needs. However competition soon sets in, and close plantations do not necessarily increase stem yield as is shown by the following figures (Table 24) for 18-months-old plantations at Adabhar.

Table 24—Growth of *Dalbergia sissoo* at close spacing at 18 months

Spacing	Survival (%)	Surviving trees (per ha)	Mean dbh (cm)	Basal area (m ² ha ⁻¹)
1 m x 1 m	92	9200	1.9	2.6
2 m x 2 m	98	2450	3.9	2.9

Assuming volume is proportional to basal area for trees of the same age, the more widely planted trees had a higher stem volume per hectare than the closely planted ones. It is possible that branch volume was greater at the closer spacing. However the considerably increased cost of seedlings for very closely spaced would rarely be justified.

Rate of growth

The yield table (Table 25, page 488–489) is reproduced from the *Master Plan for the Forestry Sector, Nepal* (Ministry of Forests and Soil Conservation, 1988). The yield is down to 5 cm top, where the mean stand diameter is greater than 20 cm. This table may be used to evaluate and compare growth data from trial plots. For instance if the top height of a stand is 11.2 m at age five years, a mean annual increment from ten years onwards of about 8 m³ ha⁻¹ can be expected, other things such as number of trees per hectare being equal. In fact 'very good' sites are rare, and many sites are 'poor' or even 'very poor'. In Sagarnath, aged five years, the following data were obtained (Table 26).

Table 26—Site quality and growth parameters at Sagarnath

Site quality	Survival (%)	Height (m)	dbh (cm)	MAI (m ³ ha ⁻¹)
High	82	14.0	10.2	17.7
Intermediate	66	9.7	8.7	3.8
Low	61	7.6	7.4	2.5

These are mean heights. Assuming top height = 1.25 x mean height, the 'high' quality falls in the 'very good' category, the 'intermediate' between 'fair' and

Table 25—Growth and yield table for *Dalbergia sissoo*

Age (yr)	Very poor site				Poor site				Fair site				Good site				Very good site					
	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹) MAI	
1	0.7	—	—	1.5	—	—	1.7	0.4	—	2.3	1.4	—	3.0	2.5	—	—	—	—	—	—	—	—
2	1.9	—	—	3.1	0.9	—	4.4	2.3	—	5.9	4.5	—	7.7	7.3	—	—	7.7	7.3	25.0	—	7.3	25.0
3	3.2	1.4	—	5.1	2.8	—	7.0	5.3	—	9.1	8.5	—	11.4	11.9	19.0	6.3	11.4	11.9	41.0	—	11.9	41.0
4	4.7	2.7	—	7.0	4.9	—	9.2	7.9	11.0	11.5	11.1	33.0	14.1	14.6	33.0	8.2	14.1	14.6	61.0	—	14.6	61.0
5	6.0	4.2	—	8.7	6.8	4.0	11.2	10.2	22.0	13.8	13.3	50.0	16.4	16.7	50.0	10.0	16.4	16.7	84.0	—	16.7	84.0
6	7.3	5.7	2.0	10.2	8.5	12.0	12.9	12.0	33.0	15.6	14.9	67.0	18.5	18.2	67.0	11.2	18.5	18.2	110.0	—	18.2	110.0
7	8.8	7.1	7.0	11.7	10.2	20.0	14.5	13.6	44.0	17.3	16.3	83.0	20.1	19.4	83.0	11.9	20.1	19.4	133.0	—	19.4	133.0
8	10.0	8.4	10.0	12.9	11.5	28.0	15.8	14.7	56.0	18.7	17.5	100.0	21.5	20.5	100.0	12.5	21.5	20.5	154.0	—	20.5	154.0
9	11.0	9.6	15.0	13.9	12.7	37.0	16.9	15.8	67.0	19.9	18.5	115.0	22.9	21.4	115.0	12.8	22.9	21.4	173.0	—	21.4	173.0
		6.0	1.7		10.8	4.1		16.9	7.4		23.3			31.2				31.2			31.2	19.2

Table 25 cont.—Growth and yield table for *Dalbergia sissoo*

Age (yr)	Very poor site				Poor site				Fair site				Good site				Very good site				
	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	Volume (m ³ ha ⁻¹)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	Volume (m ³ ha ⁻¹)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	Volume (m ³ ha ⁻¹)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	Volume (m ³ ha ⁻¹)	
10	12.0	10.5	20.0	15.0	13.8	46.0	18.0	16.8	79.0	21.0	19.4	130.0	24.0	22.2	190.0	22.2	190.0	22.2	190.0	22.2	190.0
		7.4	2.0		12.7	4.6		18.7	7.9		25.1	13.0		32.8							
11	12.9	11.0	25.0	15.9	15.0	53.0	18.9	18.0	91.0	21.9	20.0	144.0	24.9	23.0	207.0	23.0	207.0	23.0	207.0	23.0	207.0
		8.7	2.3		14.1	4.8		20.2	8.3		26.6	13.1		34.3							
12	13.6	12.3	31.0	16.7	15.4	62.0	19.7	18.4	103.0	22.6	20.8	157.0	25.7	23.7	222.0	23.7	222.0	23.7	222.0	23.7	222.0
		9.9	2.6		15.3	5.2		21.5	8.6		28.0	13.1		35.8							
13	14.3	13.2	37.0	17.4	16.2	70.0	20.4	19.0	115.0	23.2	21.4	168.0	26.3	24.2	234.0	24.2	234.0	24.2	234.0	24.2	234.0
		10.9	2.8		16.5	5.4		22.8	8.8		29.3	12.9		37.1							
14	15.0	13.9	43.0	18.1	16.8	78.0	21.0	19.5	126.0	23.9	22.0	178.0	26.8	24.7	243.0	24.7	243.0	24.7	243.0	24.7	243.0
		12.0	3.1		17.7	5.6		24.0	9.0		30.6	12.7		38.4							
15	15.7	14.5	50.0	18.8	17.3	87.0	21.6	20.0	136.0	24.4	22.6	186.0	27.3	25.2	250.0	25.2	250.0	25.2	250.0	25.2	250.0
		13.2	3.3		18.8	5.8		25.1	9.1		31.9	12.4		39.7							

'good', though the MAI is only 'fair', and the 'low' between 'poor' and 'fair'. The 'high' quality was on a site with an accessible water table, the others where there was no water table near the surface.

There is a fair amount of data on the early growth of *D. sissoo* in other localities, but very little to enable correlations with site factors to be made, and of course such factors as the intensity of weeding when the trees are young, and provenance, also have considerable influence on growth rates. A particular difficulty in making comparisons of yields is that these are expressed in a number of different ways, such as green weight of stems or stems plus branches per hectare; oven dry weight of these; and stem volumes per hectare under and over bark. The following are some very approximate conversion factors; they can vary considerably with the size and age of the tree. They are mainly applicable to trees below 20 cm dbh. (Weights in kg, volumes in m³.)

- Weight of stems plus branches / weight of stems = 1.2 (decreasing with stem diameter)
- Green weight / oven dry weight = 2.2
- Overbark volume / underbark volume = 1.3
- Oven dry stem weight / underbark volume = 600–750 (increasing with stem diameter)

Mean annual increments from three sites in the Terai, aged 5.5 years, ranged from 6.4 to 15.4 t ha⁻¹ green weight of stems and branches (Forest Research Division, 1991). This is roughly equivalent to a mean annual stem volume increment of between 4 and 10 m³ ha⁻¹. Volume, weight, and biomass tables for young plantations have been produced by Hawkins (1987a; 1987b).

Management of plantations

So far few plantations have been old enough for thinnings to be needed. K.J. White (1988b) recommends, for better growing plantations on a short rotation, thinning to 400 stems ha⁻¹ at the age of five years, and felling the remainder at the age of ten years. An alternative would be to retain 100 stems ha⁻¹ at age ten years, thus converting the stand to coppice with standards. For longer rotations for production of timber as well as other products he recommends the following schedule (Table 27). Of course the actual thinning would depend on the growth of the trees. However *D. sissoo* is sensitive to inter-tree competition and relatively heavy degrees of thinning are advisable. A trial at Adabhar of growing *D. sissoo* in mixture with *Eucalyptus camaldulensis* resulted in the growth of the *D. sissoo* being reduced by competition from the *Eucalyptus*. Some trials have been made of pollarding the trees in plantations. When a thinning is due the trees to be removed can be pollarded, rather than being

coppiced by cutting at the base. Pollarding has the advantage of removing the young growth from browsing by domestic animals.

Table 27—Thinning schedule for *Dalbergia sissoo*

Age (yr)	Stems ha ⁻¹ remaining	Approximate spacing (m)
5	620	4 x 4
10	400	5 x 4
15	100–200	7 x 7 – 10 x 10
20	50–100	10 x 10 – 15 x 14

Provenances and tree improvement

A provenance trial at Adabhar showed relatively little difference at the age of 19 months between the height growth of seven Nepal provenances, but two Pakistan provenances were markedly inferior. A later trial at Sagarnath has been reported in detail by K.J. White *et al.* (1990). The best provenance of those tested came from Kailali District in the Far Western Development Region, with individual tree volumes 16 per cent more than the average, and 25 per cent more than the worst. It also had the best stem form and branching habit. Table 28 (page 492) summarizes the results. The provenance from Hetauda was planted at Sagarnath, and the seed used in the trial was obtained from these plantings; hence the present trial can be considered as being of a Sagarnath 'land race'. In this trial the provenance from Kailali District was clearly the best but it is quite possible that other provenances equal or even superior to it will be found, and in view of the importance of *D. sissoo* a country-wide search for superior provenances would be well justified. Within this trial, and indeed in plantations generally, there is considerable variation in tree vigour and stem form. Thus by further selection of elite trees, to be propagated vegetatively in the first instance, considerable further improvement could be expected. A programme for improvement has been outlined by K.J. White (1990c). Steps would be as follows.

- Selection of provisional candidate trees, beginning with the best performers in current trials.
- Collection of terminal leaders from these trees; top-cleft grafting them in a central nursery.
- Dispatch of one-month-old grafted plants to a tissue-culture laboratory.
- Multiplication by tissue culture to produce say 1500 plants from each candidate.

- Distribution of the plants raised from tissue culture to other nurseries, for multiplication by cuttings to establish clone banks.
- From the clone banks further multiplication by cuttings to produce routine planting stock.

Table 28—Results from provenances of *Dalbergia sissoo*

District of origin	Longitude	Individual tree volume (m ³ u.b.)	Stem class (%)			Branch class (%)		
			1	2	3	1	2	3
Seti River (Kailali)	80°40'	0.0382	5	89	6	15	45	40
Koshi Tappu (Sunsari)	87°00'	0.0325	—	73	27	3	66	31
Kankai River (Jhapa)	87°50'	0.0325	—	70	30	6	57	37
Bheri River (Banke)	81°30'	0.0318	2	89	9	11	46	43
Hetauda (Makwanpur)	85°02'	0.0315	—	76	24	11	52	37
Chakraghatti (Sunsari)	87°05'	0.0306	0.5	71	29	9	57	37

Notes: Stem classes: 1, straight; 2, moderate sweep; 3, maximum sweep. Branch classes: 1, fine; 2, moderate; 3, ramicorn (repeated forking).

Pests and diseases

Sissoo wilt (*Fusarium oxysporum*) can cause a serious incidence of deaths on sites liable to waterlogging; the trees often grow reasonably well in their early years, and then die (M. Karki, 1992). The only practical control, apart from avoiding planting on waterlogged sites, is by selection and breeding for resistance to this disease. *Ganoderma lucidum*, a bracket fungus producing root rot, caused 75 per cent mortality in a 10-year-old plantation in Kailali District, but this degree of severity of attack is rare. It spreads from decaying roots of old stumps, such as where natural forest has been felled. *Polyporus gilvus* also causes root rot. Minor damage is caused by two foliage rusts (*Uredo sissoo* and *Maravalia achroa*), a leaf spot (*Phyllachora dalbergiae*) and a powdery mildew (*Phyllactinia dalbergiae*). A root-collar rot causes damage in nursery beds, and also plants raised in polypots. It is favoured by use of animal manures in the

potting mixture. It can be controlled by drenching the area with five per cent copper oxychloride. Infected polypots, including their seedlings, should be collected and burnt. The larvae of *Plectoptera reflexa* can cause serious defoliation. Young shoots and buds are eaten by langur monkeys, which will work systematically through a plantation and do considerable damage.

Uses

Dalbergia sissoo produces a strong, elastic timber, though from the shape of the bole long straight logs are difficult to obtain. The heartwood is very durable, but the sapwood is attacked by borers. The heartwood is brown with darker streaks, and is used for building, furniture, cart wheels and tool handles. It is an excellent fuelwood; according to Gamble, good pieces burn 'almost like coal'. It weighs about 780 kg m^{-3} and the heartwood has a calorific value of about $21,700 \text{ kJ kg}^{-1}$. It makes excellent charcoal.

It is a valuable fodder tree. The leaves have an average crude protein content of 15–16 per cent, with a digestibility coefficient of about 56 per cent, but the crude protein content varies considerably, being higher in young leaves than older leaves. Total digestive nutrients are about 50 per cent. The leaves fall in mid-January to mid-March (Paush to Phalgun), and the young leaves appear in March and April. In the central Terai the main harvest period is in the pre-monsoon period of mid-April to mid-June, but harvest continues through the monsoon period to mid-December (Mangsir). In India it is said that feeding of green leaves sometimes causes digestive disorders; this can be prevented by making the leaves into silage. The leaves and roots are used medicinally. The tree is an excellent source of honey.

Importance in Nepal

Dalbergia sissoo is one of the most potentially valuable species for afforestation at lower altitudes, in the Terai, Bhabar Terai and duns. In large-scale plantations it is out-yielded by eucalypts (though its lower volume yield is to some extent offset by the higher density and better quality of its wood), but for communal plantations it has the advantage of being easier to propagate (though thorough weeding is essential). It is a useful multipurpose tree, producing fuelwood, timber and fodder, and is the most widely used fodder species in the Terai. Over 90 per cent of the seedlings taken from community forestry nurseries in the Terai, for planting by farmers, are *D. sissoo*. The success rate in planting by farmers has ranged from 59 to 65 per cent.

References: A comprehensive annotated bibliography has been produced by White (1990a). Other references are: M.W. Campbell (1983a); Champion and Seth (1968b); Chaturvedi (1973b); Gamble (1922); Ghosh (1977); Indian

Timbers (1968a); Lamichhaney and Joshi (1980); Laurie (1974); Letourneux (1958); Mader and Stewart (1983); Magini and Tulstrup (1955); Napier and Robbins (1989); National Academy of Sciences (1979); Neil (1989c; 1990j); Panday (1982); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921); Webb *et al.* (1984); K.J. White (1990a; 1990b); K.J. White and Thapa (1990); K.J. White *et al.* (1990).

***Daphne* L.**

Thymelaeaceae

Nepali: lokta, kagati, kagate pat, baluwa,
baruwa, seto baluwa, kalo baluwa.

by J.P. Jeanrenaud
(with minor amendments)

Introduction and botanical description

Throughout the Middle Hills of Nepal, from the east to the far west, the inner fibrous bark or bast of three species of the family Thymelaeaceae, *Daphne bholua* Buch.-Ham. ex D. Don, *Daphne papyracea* Wall. ex Steud. emend. W. W. Smith and Cave, and *Edgeworthia gardneri* (Wall.) Meisn. (Nepali: argali) is commonly used for the manufacture of handmade paper. Of these three species, *D. bholua* is the most valuable source of raw material for this important cottage industry. *Edgeworthia gardneri* is mixed with *D. bholua* or *D. papyracea* at a ratio of 1:3; it is rarely used alone as it produces paper of inferior quality.

Daphne bholua is an erect or spreading evergreen or deciduous (var. *glacialis*) shrub, on average 1–3 m tall, but frequently attaining heights of 5–6 m in areas where it is not heavily exploited. The leaves are entire, dull green and leathery. The flowers are sweetly scented, white, flushed externally pink or purplish. Flowering is usually from December to May inclusive, depending on altitude and climatic factors. The fruit is an ellipsoid berry about 1 cm long, green at first, then purple or almost black when ripe. The fruits ripen from March to June, each fruit containing a single seed. *Daphne bholua* var. *glacialis* (W.W. Smith and Cave) Burt, is a deciduous shrub with pink to purple very sweet scented flowers appearing on bare branches in spring and occasionally in winter. It usually replaces *D. bholua* above 3000–3500 m.

Daphne papyracea is a much-branched, erect, evergreen shrub on average 1–3 m high with branches up to 3 cm thick. The leaves are dark green (darker than *D. bholua*), entire, smooth and thinly leathery. The flowers are white or greenish-white and have either a faint scent or none at all. Flowering time is from October to February. The fruit is a fleshy berry about 1 cm long, orange at first then a deep red when fully ripe. The fruit ripens from April to May.

In the past, the two species have been confused, and sometimes united as a single species, *D. cannabina* Lour. ex Wall. However field studies indicate that there are indeed two species, whose distinguishing characters are given in Table 29 which follows.

Table 29—Distinguishing features of *Daphne bholua* and *Daphne papyracea*

	<i>Daphne bholua</i>	<i>Daphne papyracea</i>
Distribution	Uttar Pradesh–S.W. China	Pakistan–Central Nepal
Altitude range	1800–3600 m (4000 m)	1600–2500 m (3000 m)
Habit	Evergreen or deciduous	Evergreen
Flowers	Heavily scented, white externally	Virtually scentless, white or greenish-white
Corolla	Usually ovate	Usually acute
Fruit	Black or purple when ripe	Orange then deep red when ripe
Leaves	Usually oblanceolate, 5–10 cm	Usually lanceolate to oblanceolate, 5–15 cm

Natural occurrence

Daphne bholua extends from Uttar Pradesh in India, through Nepal, southern Tibet, northern Assam and Bengal, Sikkim and Bhutan to south-west China. It is found from about 1800 m up to 3600 m, and occasionally *D. bholua* var. *glacialis* extends up to about 4000 m in east Nepal. However, in the west, where annual precipitation is less and the tree line correspondingly lower, it rarely exceeds 3000 m. *Daphne papyracea* occurs from Pakistan eastwards as far as central Nepal and is found between 1600 m and 2500 m, occasionally extending up to 3000 m. It is less frequent than *D. bholua* both horizontally and vertically, and appears to be generally less gregarious in habit. Both species occur widely as understorey shrubs, the former often growing gregariously in

the moist conifer and broadleaved forests of the temperate Himalaya. They are generally sparse or non-existent in more open forest and pasture land.

The density of *Daphne* stands is dependent on several ecological and biotic factors; highest densities occur between 2100 m and 2800 m on north-facing slopes. On east- and west-facing slopes the tendency is towards stands of medium density whereas the drier south-facing aspects usually display a pattern of scattered population.

The species, which are associated with a range of forest types, generally favour sites with oak, rhododendrons and *Tsuga dumosa* or *Abies* species and are also found to a lesser extent in upper mixed broadleaved forest. They are almost completely absent in forest dominated by *Pinus wallichiana*, *Cedrus deodara* and *Picea smithiana*. They prefer medium to light crown cover and usually avoid sites with dense crown cover or large open areas. Numbers also decrease in areas of intense or haphazard exploitation of the forest resource, and where there are frequent fires associated with heavy grazing. However heavy grazing by itself may increase the numbers of the unpalatable *Daphne* plants by reducing the competition from species more preferred by grazing animals (Metz, 1987).

Silvicultural characteristics and natural regeneration

Both species thrive on a wide range of soil types but generally favour moist sites with a rich, organic humus layer overlying well-drained sandy loams or Brown Earth. As cultivated plants they do well in both acid and alkaline conditions, even growing on very calcareous soils (Brickall and Mathew, 1984). Soil samples collected at Simbhanjyang on the Daman ridge (2400 m) and at Phulchowki (2800 m) in forest dominated by *Quercus semecarpifolia* gave pH readings of 5 to 5.5. Dr A.D. Schilling (pers. comm.) cites the following cultural requirements: acidic soils, warm to temperate monsoon-influenced forest, shade or partial shade as the norm. The commonest associated trees are *Quercus semecarpifolia* and *Rhododendron arboreum*.

A study of natural regeneration at a number of sites in eastern, central and western Nepal (Chauki, 2800 m; Simbhanjyang, 2400 m; Nagarkot Bal Ban, 2100 m; Kalinchowk, 2700 m; Gore Tabela, 3000 m; and Baglung District, 2230 m) revealed that regeneration takes place both through seed (approximately 25 per cent) and root suckers (75 per cent) (a root sucker is a shoot which arises from an adventitious bud on a root; Hartmann and Kester, 1976). Excavation and examination of a number of root systems indicated that suckers are readily produced from lateral roots radiating out, from a single parent plant, over considerable distances. At Nagarkot Bal Ban, roots were found to extend

up to 5 m from the stem, and there were up to eight shoots on a single lateral root (Jeanrenaud, 1984a).

Nursery and plantation techniques

Seed

Seed of *D. bholua* should be collected from the second week of April to the end of May and that of *D. papyracea*, which has a shorter season, during the last week of April and the first two weeks of May. If collected earlier most of the seed will not be viable, if later supplies will be short, as the ripe seed is very attractive to birds. The fruit should be collected before the pericarp has fully ripened, i.e. while it is still green. This is important as the flesh softens on ripening making it easier for birds to extract the seed. Contrary to opinion it is not the flesh which is eaten but the seed itself which, lacking a hard coat, is readily digested. To determine whether seed is ready for collection two simple field tests can be carried out. Grip the fruit between the thumb and forefinger and apply light pressure. If the fruit feels firm to the touch the seed is likely to be viable. Take a random sample of 10 to 20 fruit and remove the flesh to expose the seed. If ripe the flesh should be easy to separate and the seed firm and greyish-brown in colour. The seed should be placed in cloth bags and sown as soon as possible after collection as it stores badly and rapidly loses viability.

Raising seedlings in the nursery

Before the seed is sown the fleshy pericarp should be removed. In laboratory and nursery tests this was found to increase the chances of successful germination by a factor of at least ten. The seed should be sown at a depth of about 0.5 cm in trays containing either pure forest soil or sterilized sand, and where possible should be maintained at a temperature of about 22°C under plastic propagators. If trays and propagators are not available then the seed can be lined out in a standard seed bed or sown directly into polypots. The seed or soil should be kept moist, but not over-watered as there is a high risk of fungal infection. The seed should germinate within 3–6 weeks, and if there is no sign of germination within three months no seedlings will appear.

In laboratory tests, viable seed sown in mini-propagators containing sand at ambient temperatures achieved between 70 and 90 per cent germination. However, under nursery conditions (Chalnakel, 1320 m) 40–50 per cent germination was standard. It is recommended that seed is sown well before the onset of the monsoon to permit germination and seedling establishment under a controlled moisture regime; it is in any case desirable to sow the seed as soon as possible after it has been collected.

Seedlings raised in open beds or trays should be pricked out into polypots as soon as the first true leaves emerge. Any delay at this stage is likely to prove

fatal later on as *Daphne* species react unfavourably to root disturbance or exposure. Where possible polypots should be filled with soil from the seed collection area; alternatively a good, humus-rich potting mixture can be used. After pricking out the seedlings should be transplanted into polypots lined out in beds under light or medium shade (e.g. bamboo slats or broad-weave hessian sacking). They will be ready for planting out at the start of the monsoon after a year in the nursery. When planting, care should be taken to maintain the soil intact in order to minimize root disturbance.

It was noted that about 60 per cent of the seedlings from seed sown in open beds and pricked out into polypots at the start of the rains suffered from damping-off over a period of three months after germination. If fungicides are available then the problem can be minimized by regular weekly applications of Benlate, Captan or Dithane at 1.5, 0.5 or 0.5 g l⁻¹ respectively.

Vegetative propagation

Although various types of cutting are recommended for the artificial propagation of *Daphne* (Brickell and Mathew, 1984; M.W. Campbell, 1983a; 1983c; Chandler, 1969; Hartmann and Kester, 1976; Wells, 1969), recent research has shown that semi-hardwood cuttings are the most likely to succeed (Jeanrenaud, 1985). However, they may take up to 18 months to initiate roots and are generally much slower growing than seedlings, requiring two to three years in the nursery before planting out. Moreover, survival rates are low, about 40 per cent. It is therefore recommended that cuttings should only be used if seed is in short supply or unavailable.

Semi-hardwood cuttings

Semi-lignified material of current season's growth. Supple and pliable, will not snap on bending like hardwood cuttings. Cuttings should be collected from the end of June and lined out in a bed or propagator under heavy shade until rooting is initiated, after which shading should be reduced. The cuttings should be inserted in either a standard nursery soil mix (two parts soil to one part sand) or in sterilized sand and thoroughly watered in. Over-watering must be avoided, although at the same time the cutting must never be allowed to dry out. Semi-hardwood cuttings should be 10–30 cm long and 3–10 mm in diameter, preferably with a heel. The cuttings should have an axillary bud and the leaves removed, or include the growing tip and have their leaf area reduced (i.e. to one to two leaves at the apex) to minimize transpiration. Cuttings should be spaced in the beds at 5 cm x 5 cm.

Layering

The genus can also be propagated *in situ* using a simple ground layering technique. Long side branches can be bent over, covered with soil and anchored to the ground with stones. Root initiation can be encouraged by wounding or

ring-barking at the point of contact with the soil (Wells, 1969). Once rooting has occurred plants can either be detached and replanted or left to grow on (Berrisford, 1975). Layering should be carried out in June or July with rooted layers removed in the following September or October when cool mild days will help to accelerate growth until winter or dormancy (M.W. Campbell, 1983c).

Traditional harvesting

Lokta (*Daphne* bast) is usually harvested during the agricultural slack season following the festival of Dasain, i.e. from the end of September or mid-October continuing into late spring to mid-May (Kartik–Jesth), usually with two months break in the coldest months of mid-December to mid-February (Paush to Magh). Harvesting is carried out on an *ad hoc* basis with techniques varying from district to district. Generally the bark is stripped down to the rootstock and severed at ground level (thus effectively destroying the meristematic tissue and precluding coppice shoot regeneration, but probably encouraging vigorous root suckers). However, in some areas the whole plant is uprooted, a practice which should be discontinued as it prevents the potentially more vigorous regeneration from root-suckers. The Department of Forests has now issued instructions that the trees should be cut at 15 cm above ground level, before the bark is stripped.

Management for conservation and sustained yield

Based on recently collected biomass data and the results of ring analysis, a minimum rotation length of ten years is proposed. Use of shorter rotations will ultimately lead to the depletion of the resource and the collapse of the cottage industry. Therefore, to allow sufficient time for the resource to regenerate, it is recommended that no *Daphne* tree with a diameter of less than 3 cm at 30 cm from the ground be harvested (this diameter corresponds to an age of approximately ten years) (Jeanrenaud and Thompson, 1986). This recommendation has been accepted by the Department of Forests, and instructions issued to this effect. Three alternative management options are proposed. With all three options it is recommended that stems are cut through before being stripped of bark.

Block rotation on an area basis

The forest would be divided into a minimum of ten blocks, the block size depending on stocking level. Harvesters would be assigned to one block each year and would not return to that block to harvest again until the ten-year rotation was completed. Each licensed harvester would cut according to an annual quota.

Using a simple diameter gauge

Harvesting would be controlled through the use of a diameter gauge, no tree with a diameter of less than 3 cm at 30 cm above the ground would be harvested. However, cutters would not be restricted to harvesting in a particular block as in the preceding option, but would be free to harvest anywhere within the designated forest area. Thus the responsibility for resource conservation and harvesting control would rest with the individual cutter.

Combining block rotation and diameter gauge

This option would combine the two preceding systems and would prevent any harvesting, within a given block, of trees with a diameter of less than 3 cm at 30 cm above the ground. In theory, this option represents the ideal because it offers two methods of controlling harvesting intensity: rotation, and diameter related to predicted yield.

Rates of growth and yield

Growth data is rather scanty and fragmented. At Suspa in Dolakha District, on a north-facing slope at 2675 m between March and December plants above 150 cm in height had an average height increase of 7.5 cm and a diameter increase at 30 cm above ground level of 2 mm (Forest Research Division, 1991). At Baglung the height of coppice regrowth was 28 cm after one year and 75 cm after two years (Anon., 1985a). A tree 35 years old had a diameter of 14 cm at 30 cm above the ground, a height of 5.5 m, and an estimated bark production of 7 kg. The formula for estimating bark weight against age is as follows. This gives the following estimated yields (Table 30).

$$\ln \text{ usable bark in g} = -2.46 + 2.86 \ln \text{ age}$$

Table 30—Estimated yields of usable bark

Age (yr)	Usable bark (g)
5	8
10	62
15	197
20	450
25	850

The yield of bark from six 20 m x 20 m plots in 'dense stands' in Sankhuwasabha District, eastern Nepal, was equivalent to 1.03 t ha⁻¹. The total growing

stock expressed as bark in this district was estimated at 15,000 t green weight (R.K. Pokharel, 1989).

Uses

The main use of *Daphne* in Nepal is in the manufacture of handmade paper on a cottage industry scale. The paper produced is tough, pliable, elastic and durable; its manufacture goes back into remote historical times, and at one time it was widely exported to India and Tibet. More recently competition from machine-made paper threatened the industry, but there has been a revival in production of lokta paper for legal documents, horoscopes, fortune-telling cards, paintings, maps, calendars, lampshades, envelopes, and greeting cards, among many other uses. Articles made from it are especially attractive to tourists.

Apart from its main use as the raw material for manufacturing paper, the genus has acrid and vesicant properties and contains toxic resins of some medicinal value. In indigenous medicine *Daphne* yields a bitter purgative and febrifuge (Department of Medicinal Plants, 1970). The bark and leaves are used in preparations for skin infections (Chopra *et al.*, 1956), and a decoction of the roots is used as a digestive. An antileukemic principle has recently been isolated from seeds of a closely related species, *Daphne mezereum* (Kupchan and Baxter, 1975), and a nematicidal constituent from *Daphne odora* (Kogiso *et al.*, 1976). In addition, the bark of *Daphne* is insecticidal and is used to expel leeches from the noses of cattle (Bhandary and Shrestha, 1984). The bark is also plaited to make ropes and tumplines (Nepali: *tamlo*).

Importance in Nepal

Harvesting *Daphne* bark and local manufacture of paper have considerable potential in generating employment and providing income in hill areas, and for these reasons the United Nations Children's Fund (UNICEF) and other organizations have co-operated with H.M. Government of Nepal to promote the handmade paper industry. However, the resource needs careful management if it is not to be exhausted by over-exploitation. So far artificial regeneration of *Daphne* has been confined to experimental work, but it may become important to supplement the natural supplies of bark.

Another factor to be considered in connection with handmade paper manufacture is that the process requires large quantities of fuelwood to cook the paper pulp and to dry the paper. This is estimated at 3 kg fuelwood for 1 kg of paper much more than this if wood ash, rather than caustic soda, is used in the digestion process. Thus in addition to regulating the harvest of *Daphne* it is necessary to make provision for fuelwood supplies. To produce the quantities

of fuelwood needed it is likely that management of natural forest will have to be supplemented by plantations in some areas.

Research carried out to date on the ecology, silviculture and exploitation of the species has served to highlight the need for an integrated approach to management. *Daphne*, as shade-demanding understorey species, are dependent on the forest ecosystem for their habitat and thus their management must be viewed in this wider context (Forestry Services, 1984a; Jeanrenaud, 1984b; 1984c).

References (other than those quoted in the text): Abdul (1945); B.N. Acharya (1975); Anon. (1984); R.D. Bajracharya (1983); Beatty (1962); Evan Rees (1985); Forestry Services (1983a; 1983b; 1984b); Forest Survey and Research Office (1984); Gamble (1922); Haberli (1984); Maiti (1979); Messerschmidt and Pandey (1981); Suvedi and Rayamajhi (1976; 1977); Trier (1972). See also list of references in Jeanrenaud (1984b).

Daphniphyllum Blume

Daphniphyllaceae, formerly Euphorbiaceae

Daphniphyllum himalense (Benth.) Muell. Arg.

Nepali: rakchan, chandar, ragdatenden.

This section is largely derived from information provided by J. Heuch (pers. comm.). Small tree. Leaves alternate, crowded at ends of branches, simple, entire, 9–25 cm by 3–8 cm, on stalks which are often crimson, 1.5–6 cm long. Male and female flowers on different trees, crimson. Fruit a black drupe, 14 cm by 9 cm. There are two varieties. Var. *himalense*, with oblanceolate leaves with narrow tapering bases, and secondary veins not conspicuous beneath, is predominantly eastern and high altitude (2500–2800 m) in distribution. Var. *chartaceum* (Rosenth.) Huang (*D. chartaceum* (Benth.) Muell.), with oblong elliptic leaves with broadly wedge-shaped bases, and secondary veins prominent beneath, is more generally distributed, and grows from 1400 to 2300 m.

The species is found in a variety of vegetation types, often associated with oaks and Lauraceae. It often persists after much of the original vegetation has been destroyed, and in such circumstances may occur in almost pure stands. It is a shade-tolerant species and prefers moister sites. From its distribution at least some provenances must be frost-resistant, though it succumbed to frost in southern England (Lancaster, 1981). The leaves are unpalatable and are not browsed. It regenerates freely by coppice and pollarding.

The fruit ripens in November–December; it is a fleshy one-seeded drupe. There are 600–700 drupes kg^{-1} . The seed is difficult to germinate. Harrison (1989d) obtained 84 per cent germination by stratifying the seed in moist sand; mechanical scarification gave 45 per cent; and untreated seed 36 per cent. Cold water and treatment with sulphuric acid had no effect. Removal of the seed coat was harmful. One year good results were obtained by soaking the seed for two days, drying it out for two days, and repeating this process for a total of six days; but when this was repeated next year results were unsatisfactory. Other species of *Daphniphyllum* are propagated by layering or semi-hardwood cuttings. Broadcasting the seed to stabilize road cuttings has been tried, but results are unknown (Bolle, 1983). Detailed data on rates of growth are given by Levenson (1979). The following figures have been derived from his data (Table 31).

Table 31—Growth rates for *Daphniphyllum*

Age (yr)	Mean height (m)	Mean diameter (cm)	Weight of wood per tree (kg)
10	3.4	—	—
20	7.0	15	86
30	11.0	24	207

Coppice shoots grow up to 1.5 m in the first year, and reach about 25 cm in diameter when 16 years old (Heuch, pers. comm.). For management as coppice the trees may be cut at any height from ground level to one metre, when up to twenty shoots will be produced from each stool. These should be thinned out during the second year. The wood weighs about 640 kg m^{-3} and is used for fuelwood though it is not a preferred species. The new leaves are used as bedding for cattle.

References: Gamble (1922).

Dendrocalamus species see Bamboos.

***Diospyros* L.**

Ebenaceae

Trees with alternate, entire, usually rather leathery leaves; male and female flowers on different trees. Calyx and corolla with 4 or 5 lobes. Fruit a berry, usually contained in the enlarged calyx.

Key to the wild species, based on leaves and fruit

- (1) Leaves less than 10 cm long; fruit 12–35 mm in diameter, greenish-yellow, turning black, without hairs; tree sometimes spiny ***D. montana***
- (1) Leaves more than 10 cm long **2**
- (2) Leaves with the secondary veins deeply impressed on the upper surface into broad furrows, giving the leaf a wrinkled appearance; size 20 cm by 12 cm, sometimes larger, less than twice as long as broad; young leaves very hairy, older hairy beneath; fruit 25–32 mm in diameter, without hairs, yellow ***D. tomentosa* (*D. melanoxylon* in a broad sense)**
- (2) Secondary veins of leaves not as above; leaves usually smaller and more than twice as long as broad; leaves without hairs; fruit hairy **3**
- (3) Fruit egg-shaped, about 25 mm by 16 mm, covered with rusty hairs; leaves usually lance-shaped, 10–15 cm long; secondary nerves not prominent ***D. lancifolia***
- (3) Fruit globular, 38–50 mm in diameter, red and velvety; leaves usually with parallel sides, 13–20 cm long; secondary nerves distinct. Characteristic of marshy places ***D. malabarica***

***Diospyros malabarica* (Desr.) Kostel.**

(Syn. *D. embryopteris* Pers., *D. peregrina* auct. non Guerke)

Nepali: tendu, halabed, teju.

From the Terai to about 1500 m; it is one of the species associated with *Shorea robusta* in the Siwaliks. Outside Nepal it extends in India from the Jamuna (Jumna) river to Sikkim and also occurs in peninsular India; in the south east it reaches Malaysia. It is a moderate-sized evergreen tree, often found growing in swampy sites, though it will grow elsewhere on loams provided the soil is not too dry. The seedlings are very liable to damage by browsing. The fruit ripens

from April onwards; each yellow fruit contains four to eight seeds. There are about 800 seeds kg^{-1} ; the seed loses its viability after a few months, and should be sown soon after it is collected after the pulp has been removed. According to Lamichhancy and Joshi (1980), germination is improved by alternately wetting and drying the seed for 48 hours. Even fresh seed has a rather low germination percentage (5–20), so it should be sown in beds and the seedlings pricked out when they are about 5 cm high. Growth of the seedlings is slow, and the plants will need at least a year in the nursery. It is not much used for timber in India, and is mainly valued for its edible fruits. The wood weighs about 700 kg m^{-3} , but most species of *Diospyros* are not liked for fuel, as the wood gives out showers of sparks when it is burnt. The leaves are used as wrappings for *bidi* (local cheroots).

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Trotter (1958); Troup (1921).

Diospyros melanoxylon Roxb.

Nepali: tendu, abnush.

In the strict sense this does not occur in Nepal, but *D. tomentosa* Roxb. very closely resembles it and is considered by some authorities to be a form of the same species. According to Brandis (1921), *D. tomentosa* extends as far east as Nepal, though it is not included in Hara *et al.*'s Enumeration (1982). It is likely to be confined to western Nepal. In northern India it is a small crooked tree, tolerating poorer soils than *Shorea robusta*; it is used in India for afforestation of degraded sites. The seedling will withstand moderate shade, and is frost- and drought-resistant. The young plants are immune to browsing, as are the root suckers which are produced in abundance. It coppices moderately well, and pollards better.

The fruits ripen and turn yellow between April and June; each contains 3–8 seeds. There are about 1100 seeds kg^{-1} and 5 kg of fruit will produce about 1 kg of seeds. Fresh seed has a germination capacity of about 90 per cent; after storage for a year this falls to between 10 and 60 per cent. The seed may be either sown directly into polypots, after the pulp has been removed, or sown in beds for pricking out later. Alternate wetting and drying the seed for 48 hours is reported to improve germination. At Dehra Dun plants 3–6 cm tall, raised in two months, have been successfully planted (Ghosh, 1977) but this would be considered too small in Nepal, and seedlings three or four months old would be preferable. This would mean either sowing seed from the first fruits to ripen, or

storing it for the best part of a year. Stumps are reported to be unsuccessful; only 12 per cent of those planted remained alive in the second year.

It is usually too small to be of much value for timber, though the black heartwood which is developed in irregular shapes is used for small carved articles such as combs and walking sticks. The wood is heavy, about 960 kg m⁻³, but is a poor fuel as it gives out showers of sparks. Although it is immune from browsing, it is lopped for fodder in parts of India; the leaves contain about seven per cent protein, but the digestibility coefficient is very low. The fruits are edible. Its main use in India, however, is for wrappers for *bidi* from its leaves, which is a very important rural industry. To produce *bidi* leaves the trees are worked on a short, one or two year, coppice or pollard rotation.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); R.V. Singh (1982); Trotter (1958); Troup (1921).

The other two species of *Diospyros* which grow wild in Nepal, *D. lancifolia* and *D. montana*, are of lesser importance. In addition three species are cultivated in the Kathmandu Valley for their fruit, *D. virginiana* L., (American persimmon), *D. kaki* Thunb., (Japanese persimmon), and *D. lotus* L. The first two are both called *haluwabed* in Nepali.

Elaeocarpus L.

Elaeocarpaceae

Elaeocarpus sphaericus (Gaertn.) K. Schum.

(Syn. *E. ganitrus* Roxb. ex G. Don)

Nepali: rudrakshiya.

A large tree, valued for its fruit stones used in rosaries. The leaves are membranous, lance-shaped, with obscure teeth, almost hairless, and 8–15 cm long on stalks 6–12 mm long. Flowers white, in compact drooping clusters shorter than the leaves. Fruit spherical, bluish-purple, 18–25 mm in diameter. Stone grooved, with tubercles. Found sporadically in central and eastern Nepal, up to 1400 m. Outside Nepal it extends from Maharashtra to West Bengal, Bangladesh, the Malay Peninsular and parts of Indonesia. It seeds profusely, but many fruits are eaten by birds and other animals. Farmers collect the unripe fruits and mature them in an enclosure. This may account in part for the low and variable germination rates. The seed is difficult to germinate. In trials at the Pakhribas Agricultural Centre best results were obtained by cracking the

stones, giving 58 per cent germination. Treatment with concentrated sulphuric acid gave 52 per cent, and untreated seed 21 per cent. Treatment with hot water failed. Germination took 19–354 days and some continued after 18 months. Seedlings were raised in Pakhribas and planted out in July in pits 30 cm by 30 cm, filled with topsoil and compost. In January they were cut 10 cm from the ground to provide material for cuttings. These were 10–15 cm long with at least three buds. Hardwood, semi-hardwood and branch cuttings were tried, each type planted in 10 cm by 18 cm lay-flat polythene pots filled with soil and compost. The average rooting success was 56 per cent from hardwood cuttings, 31 per cent from semi-hardwood, and seven per cent from branch cuttings. Of hardwood cuttings taken in March, 62 per cent rooted; in February, 56 per cent, and in January, 49 per cent. Stool beds were established for further propagation. As mentioned, the curiously grooved and tubercled stones are greatly valued for rosaries, bracelets and other jewellery. Between 1980 and 1985 about 27 t, valued between 1 and 2 rupees kg⁻¹, were exported from Sankhuwasabha District (Sizeland, 1986). The fruit pulp is eaten by villagers, and is used for treating diseases of the head and epileptic fits. The wood is white, fine-grained, tough and elastic and weighs about 500 kg m⁻³. The tree is sometimes planted on chautaras.

References: Sizeland (1986); F. Thapa *et al.* (1991a).

Emblica officinalis see *Phyllanthus emblica*.

Erythrina L.

Papilionaceae

Nepali: phaledo

Trees with rough ridged bark; stems and leafstalks with recurved prickles; leaves with three leaflets. Flowers red, in spikes; pods 2–10 seeded. Three species of *Erythrina* are native to Nepal. *Erythrina suberosa* Roxb. Leaves densely hairy beneath. Flowers in clusters 5–10 cm long, appearing before or with the young leaves; pod hairless, 13–15 cm long, somewhat constricted between the seeds; 900–1200 m. *Erythrina stricta* Roxb. Leaves almost hairless. Flowers in one-sided clusters, 10–13 cm long, appearing before the new leaves; pod hairless, 5–10 cm long, very slightly constricted between the seeds; 1000–1600 m. *Erythrina arborescens* Roxb. Leaves with brown velvety hairs when young, becoming hairless as they grow older. Flowers in erect spikes up to 38 cm long, appearing at the end of the monsoon, between August and

October; pod covered in brown hairs, curved, 15–23 cm long; 1500–3000 m. A fourth species, *E. variegata* L. (syn. *E. indica* Lam.), is mentioned in the literature but is not included in the Enumeration of Nepal Plants; it is a south Indian species. All species are fairly similar in their silviculture.

Artificial regeneration

Seed

The seed of *E. arborescens* ripens between April and June, (Kessler, 1981) but other species produce seed between November and March. The pods are collected when they turn brown, before they open, and dried in the shade until they open naturally. There are about 2000 seeds kg⁻¹ but this is likely to vary with the species. The seed can be stored for up to five years in sealed containers. Germination rates are usually high, up to 90 per cent, and germination usually rapid, being complete within about three weeks, but seed sown in November at 1600 m took three months to germinate.

Nursery and plantation techniques

For raising seedlings direct sowing in polythene pots, with two seeds per pot, is recommended. At about 1500 m about four months in the nursery will be needed; at lower altitudes this period can be reduced. Stumps have been used in India. *Erythrina* species are also easily propagated by cuttings. Cuttings to be raised in a nursery should be taken in January or February, either from mature trees or from a few stools established in the nursery which are coppiced every year. Cuttings should be about 15 cm long, as thick as a pencil, with 3–5 buds. They are set in beds, or in large 4 inch x 7 inch (10 cm x 18 cm) lay-flat polypots containing a mixture of one part soil, two parts sand, and one part compost. They will need shade for 2–3 months after setting until roots are well formed. At low elevations cuttings taken in January or February will be large enough to be planted out at the beginning of the monsoon; elsewhere a year longer in the nursery will be needed, in which case regular root pruning and spacing is necessary. Where transport is no problem large cuttings, up to 2 m long by 5–8 cm in diameter, and planted straight out in the field, give very satisfactory results and of course eliminate the time taken for seedlings or small cuttings to reach these dimensions. In many parts of the world these are used for living fence posts.

Growth rates

There is not much data on early growth, but there are indications that young seedlings grow rather slowly. Near Pokhara, two-year-old seedlings averaged 47 cm in height (M.B. Karki, 1988), and at 1400 m in eastern Nepal, on a sandy loam with an east-southeast aspect trees took 3–4 years to reach 1 m in height

(Sizeland, 1986). Once established growth is rapid. Gamble (1922) reports a mean annual diameter increment of *E. suberosa* of about 1.3 cm.

Uses

The main value of *Erythrina* species is as fodder, and for this they quite important in some localities, while in others they are little used. In one of the three village studied by Hawkins and Malla (1983) they constituted about 21 per cent of trees used for fodder, and in a second panchayat 13 per cent. The trees are lopped between September and January, after which they drop their leaves. The leaves have a crude protein content of about 17 per cent (D. Bajracharya *et al.* 1985). The wood is very light and soft, about 300 kg m⁻³, and hence is a poor fuel; it is used in India for planking and small articles. In itself *Erythrina* does not make a good hedge, as it is a single-stemmed tree with no low branches. Cuttings, however, can be used as live fence posts to which barbed wire is attached. *Erythrina* species, in particular *E. arborescens*, are often planted for ornament.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Kessler (1981); Lamichhancy and Joshi (1980); Napier and Robbins (1989); Panday (1982); Rao and Purkayastha (1972).

Eucalyptus L'Herit.

Myrtaceae

Nepali: mashala

Eucalypts

Natural occurrence

Most eucalypts are natives of Australia, but a few occur in Papua New Guinea and Indonesia, while one species, *Eucalyptus deglupta*, reaches the Philippines. Different species, among the five hundred or so which form the genus, occur naturally on sites ranging from mountains with frequent frosts and snow, to tropical forest and hot semi-deserts. At low altitudes, in monsoon climates with a marked winter dry season, it has been found that with few exceptions the most suitable species and provenances come from areas with a summer rainfall in Australia, that is the north and northeast of the continent. At higher altitudes a wider range of species can be grown, including some from winter rainfall areas.

Silvicultural characteristics

Almost all eucalypts are evergreen and are characterized by the possession of indefinite shoots and naked buds, and do not develop resting buds. The indefinite shoot continues to produce pairs of leaves at regular intervals. In the axil of each leaf there is a naked bud which can immediately produce a shoot of the next order, or, if the main growing tip is destroyed, can take over the task of becoming the main shoot in a very short period. As long as favourable conditions of growth persist, the shoots will continue to grow in height and length and produce new orders of branches. This continuous growth contrasts with that of many species of trees, where growth tends to be intermittent. These characteristics enable eucalypts to grow very rapidly and to yield high volume increments if climatic and soil conditions are suitable (Jacobs, 1979). In their native countries growth of eucalypts is reduced by the activities of leaf-eating insects, but in most countries where eucalypts have been planted as exotics these insects have not yet appeared, and so growth of the trees is even more rapid than in their native habitat.

Nearly all species of eucalypt are intolerant of shade, and must be planted in completely open conditions. With a few exceptions they in turn cast relatively light shade, and in areas where tall perennial grasses thrive persistence of these grasses under a eucalypt plantation may cause problems, especially from the danger of fire. Eucalypts are also very intolerant of competition by grass and other vegetation when young, and satisfactory growth can only be obtained through very thorough weeding. This is extremely important in plantations designed to produce high yields of fuelwood, especially in the Terai where grass competition tends to be severe, as has been shown in a replicated trial at Adabhar in the Bhabar Terai. *Eucalyptus camaldulensis*, Petford provenance, was planted in July 1982 and received the following treatments: (a) total cultivation for 18 months after planting; (b) weeding in spots 50 cm in diameter for 18 months (c) grass cutting and mulching. Results at 18 months were as follows in Table 32.

Table 32—Height growth of *E. camaldulensis* after different weeding treatments

Treatment	Survival percentage (%)	Mean height (m)	Percentage height of treatment (a) (%)
(a) total cultivation	94	6.8	100
(b) 50 cm spots	94	3.2	47
(c) grass cutting	75	2.0	29

Thus even at the early age of 18 months trees receiving the full cultivation treatment were over twice as tall as those only having spot cultivation. Weeding by cutting the grass only was very ineffective. Clean cultivation by hand is very expensive, but the costs can be reduced by allowing farmers to cultivate crops between the trees. This may result in a slight loss of increment, but the loss is outweighed by the much lower costs. Inadequate weeding is the probable explanation of many recorded instances of failure or poor growth in *Eucalyptus* plantations. If the growth of young eucalypt plants is hindered by adverse influences, such as insufficient water, or root congestion within a polypot, they may go into check from which they take a considerable time to recover. It is important, from the time the seed germinates until the seedling is fully established in the plantation, to avoid, if possible, anything which may cause a temporary check to growth.

As is to be expected in a genus with such a wide range of natural habitats, species of *Eucalyptus* vary enormously in their resistance to frost and drought, and in their adaptability to different types of soil. However relatively few species grow well on soils with a high content of free calcium. Eucalypts form mycorrhizal associations with fungi, but vigorous stock of most species can be raised without deliberate inoculation.

Most commonly planted species coppice freely. One exception is *E. deglupta*. In some areas *E. cloeziana* has been reported to coppice poorly, but elsewhere it coppices well. The coppicing ability of *E. grandis* is reported to decrease after the age of 10 to 12 years (diameter probably over 30 cm).

Most eucalypts occur in regions subject to frequent forest fires, and hence have developed various means of protection, and recovery after fire damage. Many species, for instance, have thick barks which reduce the danger of fire damaging the cambium. After burning eucalypts frequently develop large numbers of epicormic shoots which eventually give rise to new branches, or, if the stem is severely damaged, coppice shoots may arise from the base. Many species develop lignotubers at the base of the stem, so that, if the aerial parts of even young seedlings are destroyed by fire or other causes, new shoots can develop from the lignotubers. One species of eucalypt which is very sensitive even to light ground fires is *E. deglupta*, the natural habitat of which is tropical rain forest where fires do not occur as long as the forest is undisturbed by man's activities.

There has recently been a great deal of often ill-informed criticism about planting eucalypts, on various grounds, one being that they use excessive amounts of water. Eucalypts are fast-growing species, and to produce large quantities of wood large amounts of water are needed. However trials in India

have shown that of the species tried, *E. tereticornis* was the most efficient in the ratio of water consumed to biomass produced (Chaturvedi *et al.*, 1988).

Choice of species and provenances

In the Terai the fastest-growing species are *E. camaldulensis* and *E. tereticornis*; in general the former species is the faster of the two, but the latter is of better form and would be desirable if production of poles was important. Another potentially high-yielding fuelwood species for this area is *E. urophylla*, but it is still under trial and it will be a few years before its real potential is known. For the production of straight poles *E. cloeziana* and *E. citriodora* could be considered. *Eucalyptus grandis*, a species which is widely planted in parts of tropical Africa, and under good conditions grows extremely rapidly, has only been tried on a small scale at lower altitudes, and with rather poor results generally, with one exception.

Above 1000 m although there are some very vigorous individual trees, for instance in the streets of Kathmandu, so far it cannot be said that any species of *Eucalyptus* has shown outstanding promise, despite numerous trials made between 1972 and 1978, mainly in the Kathmandu area. In general *Eucalyptus camaldulensis* and *E. tereticornis* have done best up to about 1500 m, and *E. grandis* and *E. globulus* subsp. *maideni* between that level and 2000 m, but in every case growth has been rather poor for eucalypts. Very few trials have been made above 2000 m, where frost becomes a real problem, and almost all have failed. If planting of eucalypts at these altitudes is ever envisaged such frost-resistant species as *E. globulus* subsp. *bicostata*, and possibly even such species as *E. johnstonii* and *E. urnigera* could be tried. Lists of cold-resistant species are given in Jacobs (1979).

It should be noted that a number of species which thrive at high altitudes in other parts of the tropics, in particular *E. globulus* subsp. *globulus* which is an important plantation species in the Nilgiri Hills of India, and also in Ethiopia and Kenya, do not tolerate the more severe conditions of the hills of Nepal. It is very likely that the poor results obtained from eucalypts away from the Terai are due in part at least to inadequate weeding at the time of establishment, and subsequent neglect. However clean weeding, or intercropping, on steeply sloping land would be undesirable, even if economically feasible. In any case eucalypts cannot be regarded as priority species in the hills of Nepal at present. Multipurpose species, especially those producing fodder, are considerably more important.

Provenance is very important in many species of eucalypt, especially in those with a wide natural range, such as *E. camaldulensis*. On a given site volume production of the best provenance of this species may be eight times as high as

that of the worst provenance. Provenances may also differ considerably in their tolerance to site factors such as drought, cold, and unfavourable soil conditions. Generally the provenances most suited to Nepal conditions have come from northeast Queensland, north Australia, and the northern parts of West Australia, and almost always from regions with a marked summer rainfall. More details of the provenances found most suitable in Nepal will be given in the accounts of the individual species.

Artificial regeneration

Seed

The capsules are collected from the tree when brown, spread on sheets of paper to dry in the sun, and shaken from time to time to release the seed. It should be noted that many species of eucalypt hybridize freely with related species, so seed should not be collected from trees growing near to other species of eucalypt. Until seed stands of superior provenances are established in Nepal it will be necessary to import most supplies from Australia. The weight of the seed varies with the species, but in general eucalypt seed is very light, with 100,000 to 800,000 viable seeds kg^{-1} for the commonly planted species. Seed, as collected, is mixed with unfertilized ovules, known as chaff, which greatly outnumber the fertile seeds. It is not necessary to try to separate the seed from the chaff. Numbers of seeds kg^{-1} given below are for seed mixed with chaff. Seed should be stored in sealed polythene bags. If kept in a cool place it will retain its viability for several years. Germination of the fertile seed is usually good, up to 80 per cent.

Nursery and plantation techniques

To raise seedlings the seed mixed with two to three times its volume of fine dry sand is sown in sand or sterilized soil in boxes or trays. Such trays should contain a layer of small stones about 1 cm deep covered by 5 cm of soil, and have adequate drainage holes. Before the seed is sown the tray should be thoroughly soaked, preferably by watering from below, and allowed to drain. After sowing the seed it should be covered with a layer of sand just sufficient to cover it. Sowing rates should be based on germination percentages, assuming that about half the viable seeds will produce seedlings for transplanting, and designed to produce about 4000 seed m^{-2} . (At Sagarnath the aim is to produce 10,000 seed m^{-2} .) If no information is available on germination rates 10–15 g m^{-2} should be sown. Generally no fertilizer should be needed in the seed trays. However if growth in seed trays is very slow, watering the seedlings with a very dilute solution of soluble fertilizer containing nitrogen and phosphorus will help to speed it up. Whether fertilizer is needed in the potting mixture in the polythene bags will depend on the nutrient content of the soil in the mixture.

Germination will generally take 4–7 days. The seedlings are pricked out into polythene bags when they have produced their first pair of true leaves, which will normally take 10–12 days. The seed trays should be kept under partial shade until the time for pricking out arrives, and the pricking out also should be done under shade. The potted seedlings should be kept under shade for two days, then moved out into the open.

Seedlings at the time of planting should generally be between 20–30 cm tall, with a root collar diameter of 1.5–2.5 cm. However the actual size is less important than that the plant should continue in full vigour from sowing the seed to planting in the field, and should not at any time be subject to check during its growth. In the Terai, 8–10 weeks in the nursery will be needed to produce plantable seedlings; in the duns and inner Terai about two weeks longer. (At Sagamath 5–8 weeks are used to raise 12–15 cm plants, but nursery conditions such as shade and watering are carefully controlled, and also great care is taken in planting). Nursery growth is very rapid in June and July, so seedlings to be planted in the last two weeks in July will need about two weeks less in the nursery (though this is later than the optimum time for planting). The use of overgrown plants is not recommended, but if they have to be used they can be cut back to a height of 20 cm.

In Sagamath where several hundred thousand seedlings are raised each year a factory production line approach is used. Soil in trays and polypots is sterilized by heating for 30 min at 60°C. Galvanized seed trays 25 cm x 30 cm x 8 cm are used, and they and all other equipment are sterilized by using one per cent solution of copper oxychloride. The water for the seed trays is similarly sterilized. The trays with the germinating seed are covered with glass sheets and paper, removed after 3–4 days. Seed trays are kept in a germinating chamber, roofed with fibre glass, in which the air humidity is kept constantly high by use of a fine mist spray. Temperatures during this germination period are maintained between 28 and 39°C, and humidity at 52–70 per cent between 0900 and 1500 hours. After pricking out, the seedlings are kept in 93 per cent shade for two nights, and then stood out in full sunlight. More details can be found in K.J. White (1988c).

In some countries direct sowing of eucalypt seed into polythene bags has been practised, but this is difficult as the seeds are very small and mixed with many times their volume of chaff. This method involves considerable waste of seed and should only be tried when seed is cheap and plentiful. There are also difficulties in measuring out the very small quantities of seed needed per bag. At least at present in Nepal conditions sowing trays, and then pricking out, is more satisfactory.

Where termite attack on young seedlings in plantations is a serious problem it may be necessary to mix insecticides in the potting mixture in the polythene bags; those commonly used are dieldrin and aldrin. Fortunately in Nepal, so far, severe termite attack has not occurred, and the use of such insecticides, which are persistent organochlorides, is unnecessary.

In tropical conditions planting eucalypts as bare-root plants has nearly always been found to be unsatisfactory.

The use of cuttings will be needed mainly for clonal propagation of large numbers of selected trees. In general it is difficult to make cuttings from old wood, such as the branches of growing trees. They can, however, be taken from coppice shoots, epicormic shoots, and seedlings. Details of the methods for raising *Eucalyptus* cuttings at Sagamath are given in K.J. White (1988c). Clone banks are established each containing 500 plants, at 1 m x 1 m spacing. These are irrigated during the period from October to February. Coppicing begins in March and should be done 25–30 days before the cuttings are harvested. Harvesting begins very early in the morning (0500 hours) and should be completed at 0700 hours.

The cuttings are placed in buckets of water and kept under continuous mist spray. They should have 1–4 internodes. After cutting the tips, branches, and thick base parts are removed, and leaves cut so that their area is reduced to about one third. They are kept in a sterilizing solution of 1 g l⁻¹ copper oxychloride until they are planted out into polythene bags. Before they are put into the bags the basal 1.5 cm is dipped into a rooting hormone powder. They are kept in a controlled environment for 3–4 weeks, and then hardened off for another 1–2 weeks. In this controlled environment there should be a high light intensity, high humidity from misting, and temperature 25–30°C. They should remain in this environment until they have developed 3–4 leaves and an adequate rooting system.

Plantation techniques

Planting should be as early as possible at the beginning of the monsoon. At Sagamath planting begins as soon as the top 25 cm of soil have been thoroughly wetted, usually in mid-May, and should be completed by the last week in June. The planting is done immediately after pitting. If the top layer of soil has dried out it should be removed, and only damp soil should be used to pack around the seedling. For commercial plantations a spacing of 2 m x 5 m should be used. This gives a longer period in which cultivation of crops between the trees is possible, and has very little influence on total volume production as compared with closer spacing. For production of small fuelwood on very short rotations for domestic use closer spacing, down to as little as 1 m x 1 m can be used (see,

for instance, *E. camaldulensis*), though providing seedlings for this close spacing is expensive.

The importance of thorough weeding has already been mentioned, especially when there is heavy grass competition. Clean cultivation is the ideal, but in general costs too much, and in the Terai the cultivation of agricultural crops between the trees is the best alternative. In the Middle Hills this may not be possible on steeply sloping land, because of the danger of soil erosion. Weeding in patches 60–100 cm in diameter, or better in strips of this width along the contours, may be all that can be attempted, but this will certainly result in poorer growth.

In some parts of the world eucalypts suffer from boron deficiency. The symptoms vary to some extent between species; often the first to be observed is the dying back of the leading shoot towards the end of the dry season, accompanied by crinkling and discoloration of the upper leaves. This discoloration occurs between the lateral veins, starting at the leaf margins and proceeding towards the midrib. It may be yellowish at first, later turning purple, or may remain yellow. The next stage is the dieback of the leading shoot. In cases of severe boron deficiency this dieback may be repeated for year after year, producing a very crooked and branchy stem.

No evidence of boron deficiency in eucalypts has yet to be confirmed in Nepal, and trials of added boron have not produced any response. If it should occur it can be corrected by application of fertilizer grade borax, at the rate of 25–50 g per tree, in a circle round the tree or in two patches, one on either side, 15–30 cm from the plant. Care should be taken that the borax does not come into direct contact with the plant. It should be applied about four weeks after planting. If symptoms are later seen in older trees, they can be treated in a similar way. Foliar applications of borate are less effective. It is standard practice to apply NPK fertilizers to eucalypts in some of the world. Some trials on the use of such fertilizers have been made in Nepal, but to date the results are inconclusive.

Susceptibility to adverse influences

No serious pests or diseases of eucalypts have yet been recorded in Nepal. In some countries where eucalypts have been planted as exotics defoliation by the eucalyptus snout beetle, *Gonipterus scutellatus*, is a serious problem but fortunately so far this insect has not reached Nepal. Serious damage by fungi is also absent; the two most dangerous species, *Diaporthe cubensis* and *Corticium salmonicolor*, are favoured by a continuously warm and humid climate, such as does not occur in Nepal.

In many countries termite attack is so severe that it is impossible to establish *Eucalyptus* plantations without the use of insecticides. Fortunately in general this does not apply to Nepal, though some cases of termite damage have been reported from Adabhar. Prevention is by including the insecticides dieldrin or aldrin in the potting mixture; both of these are harmful to the environment, and indeed are prohibited or very severely controlled in many countries, so they should certainly not be used unless absolutely necessary.

Many eucalypts are susceptible when young to damage by browsing animals, including domestic animals, and protection is necessary. Those species which have glaucous juvenile leaves, such as *E. globulus* and its subspecies, are less palatable and are generally avoided by browsing animals. As mentioned above, most species are to some extent fire-tolerant, and once the stems have reached a diameter of 10 cm or so they will often survive light grass fires. However, although the trees may not be killed, they are still damaged, and growth is reduced. One effect of fires is to cause the production of numerous epicormic shoots, and especially where there is an accumulation of inflammable material near to the base of the stems scars may be produced, which are possible sites for the entry of pathogens. Thus a policy of protection against fire should be adopted.

Yields

Intensively managed eucalypt plantations can produce very high yields, up to more than 40 m³ ha⁻¹ annually. The highest yields have usually been obtained in the humid tropics where there is no pronounced dry season, and in Nepal it is not to be expected that such high yields will be attained. However, well-managed plantations in the Terai of suitable provenances of *E. camaldulensis* and *E. tereticornis* should be capable of producing 20 m³ ha⁻¹ yr⁻¹ or more. It should again be emphasized that such yields will not be obtained without intensive cultivation. More details of growth and yield will be found under the descriptions of the individual species.

Uses

Although many eucalypts produce sawn timber of high quality in their native country, there are often difficulties in producing sawn timber from plantations of some fast-growing species. This is due to the development of strong growth strains within the stem, which tend to cause warping and splitting, and sometimes collapse of the timber after sawing. Techniques exist for overcoming these difficulties, and they are not equally severe in all species; for instance good quality furniture has been produced from *E. camaldulensis* in Nepal. However the main value of eucalypts in Nepal is likely to be for high volume

production of fuelwood and poles, on short rotations, mainly in the Terai and Bhabar Terai.

Eucalypts produce excellent fuelwood. For many years they provided the fuel for the locomotives of the East African Railway, between Kenya and Uganda. The fuelwood supply of Addis Ababa, in Ethiopia, comes largely from *E. globulus* originally planted by the Emperor Menelik, a little less than a hundred years ago. The calorific value of dry wood varies from 19,700 to 21,000 kJ kg⁻¹. Calorific value on a volume basis depends on the density of the wood. Figures for wood density, based on Bolza and Keating (1972) (quoted in Jacobs, 1979) are given under the descriptions of the different species. It must be borne in mind that density may vary considerably with the age of the tree and conditions of growth; in general older trees have denser timber than younger ones. Eucalypt wood easily makes good strong charcoal. In many countries eucalypts are extremely important as a source of pulpwood for paper manufacture.

Eucalypts are in general not of much value as fodder trees, though the leaves of some species are eaten by sheep and cattle in Australia in times of scarcity. The leaves of older trees are used, and allowed to dry for a day or two before being eaten. As they are astringent a change of diet is necessary after a few days. Most species are excellent honey producers, and many are important sources of essential oils for medicinal purposes, and for perfume.

Importance in Nepal

In the Terai and at lower altitudes eucalypts have been shown to be among the best species for high volume fuelwood production, as the very successful plantations at Sagarnath demonstrate. At higher altitudes, broadly speaking, success in plantations has not yet been achieved, despite good growth of individual trees on some sites. Eucalypts have been raised on a small scale in Community Forestry Development Project nurseries, mostly for issue to individual farmers. In the years 1981 and 1982 they amounted to 0.5 per cent of all seedlings issued, according to the sample survey made by J.G. Campbell and Bhattarai (1983b). Average survival was 46 per cent, as against an average for all species of 68 per cent. Apart from such small-scale issue to individual farmers eucalypts cannot be recommended for community forestry plantations in the hills, at least as far as existing knowledge goes. Even if species more suited to the site conditions were eventually to be found, satisfactory growth of eucalypts requires skilled nursery technique, reasonably fertile soils, and above all very thorough weeding. Under present conditions less exacting species are to be preferred.

***Eucalyptus camaldulensis* Dehn.**

(Syn. *E. rostrata* Schlecht.)

Bark in various shades of white, buff, and grey, peeling off in strips or irregular flakes. Leaves narrow, tapering from base to apex, often curved, on long stalks. Flowers in umbels of 5–10; cap of bud usually narrowed into a beak. Fruit 5–7 mm in diameter, base hemispherical, disc broad, valves protruding.

Origin

Eucalyptus camaldulensis is the most widely distributed of all eucalypts, ranging from Victoria and South Australia to the northernmost point of northern Australia, though tending to be absent from the area adjoining the east coast. It grows under winter, uniform or summer rainfalls ranging from 250 to 625 mm. With this very wide range of conditions in its natural habitat, the selection of the best provenance is extremely important. It was introduced to Nepal about a hundred years ago, and some very large trees are to be seen in Kathmandu. These were probably of a southern Australian provenance. Provenances from the northern, summer rainfall regions of Australia, which are more suitable for plantations in Nepal, were first introduced about 1970.

Silvicultural characteristics

In Australia it grows from 25 to 50 m high, often with a relatively short bole and a spreading crown; in plantations, however, clean boles are produced. The straightness of the stem varies with the provenance. It tends to cast rather a light shade. In Australia it grows in regions with from 0 to 50 days of frost per year. Here again resistance to frost varies with the provenance. Damage attributed to winter chill has been recorded from Hetauda and some other localities (K.J. White, 1988b). It is said to follow abrupt changes in minimum temperature. The symptoms are leaf distortion, followed by yellowish or reddish discoloration, and death of young buds, soft tips, and green stems. These symptoms are somewhat similar to those caused by boron deficiency in other parts of the world. All provenances recommended for Nepal are tolerant to winter drought. Larger trees are fairly resistant to fire, and even severely damaged trees will coppice successfully if felled immediately. In young plantations, however, fires cause numerous deaths and considerable loss of growth.

Artificial regeneration

There are 770,000 viable seeds kg^{-1} and the sowing rate in seed trays is 10 g m^{-2} . In the Terai successful establishment of plantations depends on intercropping with agricultural crops, clean weeding being ruled out on the grounds of

expense. An experiment planted at Adabhar in 1982 gave the following results, after 2.5 years (Table 33).

Table 33—Growth of *Eucalyptus camaldulensis* with intercropping

Treatment	Survival (%)	Height (m)	dbh (cm)	MAI ($\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$)
Total cultivation for first 18 months only	97	8.9	6.6	16.8
Total cultivation for first 18 months plus cowpea	92	7.1	5.4	10.4
Patch cultivation in 75 cm radius circle round plants	100	4.5	3.0	3.6
Patch cultivation as above plus cowpea	75	3.6	1.9	0.4

Cowpea is not good for intercropping. It is an annual and hence was only effective for one monsoon; it is also a twiner and tends to swamp the young *Eucalyptus*. Similar results were obtained at Sagarnath. A plot ripped and hand cultivated three times had a mean annual increment at age 4.7 years of $23.8 \text{ m}^3 \text{ha}^{-1}$; on a similar soil at the same age one which was only patch weeded had an increment of $0.9 \text{ m}^3 \text{ha}^{-1}$ only. Crops preferred at Adabhar are as follows (Table 34).

Table 34—Crops for intercropping with *Eucalyptus* species

	Summer	Winter
Pre-planting	early maize	sesame
First year	groundnuts (sandy soil); maize (silty soils)	potatoes or tori (rape); musur dhal (lentils); tobacco (after maize)
Second year	early maize (sands and silts)	sesame or jhuse til (<i>Guizotia</i>) or tori and musur dhal
Third year	maize as a fodder crop, <i>Stylosanthes</i> 'verano'	sesame or jhuse til

In the third year yields are expected to drop. This cropping scheme is not rigid, and can be modified to suit farmers' needs. Some crops are undesirable, for

instance sesame in the first planting year, as it tends to swamp the eucalypts. Possibilities under older plantations include pineapples, *Rauwolfia*, and fodder crops, but so far only small-scale trials have been made of these.

Trials have also been made of intercropping *E. camaldulensis* with essential oil plants; the *Eucalyptus* is also, of course, a potential source of essential oils. At Tamaghari, Bara District, the trees were interplanted with *Cymbopogon martinii* (palmarosa grass) and *C. nardus* (citronella grass). Before planting the *Eucalyptus* seedlings were cut back and allowed to re-sprout; by planting time they averaged four shoots each, 2.5–5 cm long. Planting distance was 5 m x 5 m. Five months after planting most of the *Eucalyptus* were pruned to single stems. About nine months after planting the trees in the citronella plot averaged 2.3 m in height with a ground level diameter of 3.4 cm, while those in the palmarosa plot, where the grass had grown to 2 m tall, and suppressed the *Eucalyptus*, the average height was 1.7 m and the diameter 2.2 cm (Adkins, 1988).

At Sagamath ripping the ground before planting increased the volume at 4.6 years old by slightly over one per cent, which is negligible. As ripping is an expensive operation requiring heavy machinery its use would only be justified on sites with very hard soils, or a hardpan near the surface.

Growth rates

The following yield table (Table 35, page 522) is reproduced from the *Master Plan for the Forestry Sector, Nepal* (Ministry of Forests and Soil Conservation, 1988). The yield is down to 2 cm top. K.J. White (1988b) bases Site Quality (SQ) Classes on mean annual increment. Site Quality 1 produces a mean annual increment of 20–30 m³ ha⁻¹ yr⁻¹; Site Quality 2, 10–20 m³ ha⁻¹ yr⁻¹, and Site Quality 3, less than 10 m³ ha⁻¹ yr⁻¹. In Sagamath 92 per cent of the area is SQ 2, seven per cent SQ 3, and less than one per cent SQ 1. White's Site Quality 1 corresponds roughly to 'very good' on the yield table, if MAI at age five is taken as the criterion; Quality 2 is 'fair' to 'good' and Quality 3 is 'poor' to 'very poor'.

At Adabhar well-tended plantations have produced between 15 and 23 m³ ha⁻¹ yr⁻¹. At two stations in the eastern Terai growth rates have been poorer. At the age of 5.5 years, plantations at Belbari and Tarahara had a mean annual increment of 7.8 and 9.6 t ha⁻¹ yr⁻¹ of wood, fresh weight, respectively, equivalent to a volume increment of about 7 and 8.5 m³ ha⁻¹ yr⁻¹ respectively. None of the older trials at altitudes above about 500 m grew very well, the best being at Trisuli where a provenance from Gibb River, Western Australia, grew to a diameter of 11.3 cm in six years; 'poor' according to the yield table. However as mentioned previously, tending of these trials may have been inadequate.

Table 35—Growth and yield table for *Eucalyptus camaldulensis*

Age (yr)	Very poor site				Poor site				Fair site				Good site				Very good site				
	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)	Top height (m)	dbh (cm)	Volume (m ³ ha ⁻¹)
1	1.5	—	—	2.1	—	—	2.8	1.2	—	—	—	—	3.5	2.2	—	—	4.2	3.4	—	—	—
2	3.9	1.3	—	5.6	2.7	—	7.4	4.1	—	—	—	—	9.3	5.4	11.0	—	12.0	7.3	23.0	—	—
3	5.9	3.1	6.0	8.2	5.0	12.0	10.8	6.7	19.0	13.7	8.4	32.0	16.6	10.2	35.0	—	10.2	10.2	35.0	—	—
4	7.5	4.9	12.0	10.3	7.2	23.0	13.3	9.3	40.0	16.3	10.9	63.0	19.3	11.2	15.8	—	10.5	16.1	23.8	—	—
5	9.0	6.7	22.0	12.0	9.4	42.0	15.0	11.4	64.0	18.0	13.2	95.0	21.0	15.4	19.0	—	15.2	15.2	138.0	—	—
6	10.3	8.4	33.0	13.4	11.3	62.0	16.4	13.3	94.0	19.4	15.1	122.0	22.5	19.4	20.3	—	21.1	21.1	276	—	—
7	11.6	10.1	48.0	14.8	13.0	82.0	17.8	15.0	116.0	20.8	16.8	159.0	23.8	23.4	22.7	—	26.1	26.1	30.5	—	—
8	12.8	11.6	63.0	15.9	14.3	102.0	18.9	16.3	147.0	21.8	18.1	190.0	24.8	26.4	23.8	—	30.4	30.4	31.3	—	—
9	13.7	12.9	79.0	16.6	15.6	121.0	19.8	17.6	169.0	22.4	19.3	215.0	25.4	29.0	23.9	—	32.9	32.9	31.1	—	—
10	14.3	14.1	95.0	17.2	16.6	138.0	20.4	18.7	186.0	23.0	20.4	232.0	26.0	30.6	23.2	—	35.1	35.1	30.1	—	—
		15.1	9.5		20.3	13.8		25.8	18.6								22.2	22.2	287.0		

Later trials planted at 1500 m indicate that *E. camaldulensis* is 'a species with much potential in the middle mountains' (Neil, 1989b) but no growth details have been seen. In addition to site quality, growth is obviously affected by plantation establishment methods, particularly the intensity of weeding, and provenance. Volume increment is also affected, within limits, by spacing. Most of the growth figures quoted above are from the Petford provenance. Volume and biomass tables have been prepared by Hawkins (1987a; 1987b).

Choice of provenances

As mentioned previously provenance is extremely important with *E. camaldulensis*. In Nepal only provenances from summer rainfall regions are likely to be at all successful; these come from northern Queensland, northern Australia, and the north of West Australia. Of these the Petford provenance from Queensland was found to be the best in most trials made in the Terai. This provenance is in some respects intermediate between *E. camaldulensis* and *E. tereticornis*, and has been very successful in many countries (Venkatesh and Vakshaya, 1979). More recent trials have shown that there are some other provenances which rival Petford in growth rates, and in some cases may exceed it, one of these being Emu Creek. Some of these come from very near to the original Petford site. K.J. White (1988b) suggests the following (Table 36) for different soil types in Sagamath.

Table 36—Provenances and soil types

Well-drained, sandy soils	Silty soils	Silty clay soils
Emu Creek, Petford	8.1 km from Petford	8.5 km from Dimbullah
Wrotham Park	Emu Creek, Petford	Katherine, N.T.
16 km NE Petford	7 km NW Irvinebank	Gibb River, W.A.
7 km NW Irvinebank	Wrotham Park	Emu Creek, Petford
Lappa Junction (nr Petford)		

Notes: Included with well-drained, sandy soils are soils with a humic-stained horizon 20–30 cm deep; silt loams over deep sandy loam or sand; other sandy soils; water table 20 m or more deep; drought prone. Silty soils have a humic-stained upper horizon to about 20 and are silt clay loams overlying silty sandy loam or sand; they tend to be brick-hard in the dry season, and become compacted when leached or heavily grazed; seasonally dry. Silty clay soils are humic-stained silty clays to 40 cm deep overlying sands and gravels.

For future development of large-scale plantations in the Terai more widely distributed trials of these provenances would be desirable. However greater gains in production might be obtained from clonal production from selected trees within already tried and proven provenances.

Spacing and thinning

Some trials have been made of very close spacing, the aim being to produce high volumes on very short rotations on small areas, such as a farmer might be able to find to produce the fuel needed for his family. At Adabhar the following results (Table 37) were obtained from *E. camaldulensis*, Petford Provenance, at the age of 18 months (Hawkins, 1986).

Table 37—Spacing and growth of *Eucalyptus camaldulensis* at Adabhar

Spacing	dbh (cm)	Height (m)	Fuelwood, oven-dry (t ha ⁻¹)
1 m x 1 m	3.1	5.9	36.2
2 m x 2 m	5.3	7.0	34.5

Four times the number of trees increased volume production by only five per cent; clearly 1 m x 1 m is too high a stocking for an initial rotation of 18 months. Hawkins considered that 1.5 x 1.5 m would be the optimum stocking for short rotations (first cutting at 18 months), but as far as is known no trials have been made at this spacing.

For more normal fuelwood rotations K.J. White (1988c) has shown that near the age of five there is little difference in total commercial volume production between stands ranging from 2 m x 2 m to 2 m x 5 m spacing, as Table 38 from a trial 4.7 years old at Sagarnath shows. Effective stems are those that are expected to contribute to the final commercial crop volume, as opposed to ineffective or suppressed trees the growth of which has slowed down or ceased, and which generally do not form part of the commercial harvest (though they may be of importance for fuelwood for local people). Whether they are removed or not has little effect on the growth of the remainder of the stand. In stands of moderate to high productivity, White regards trees less than 6 cm in diameter at 1.8 years, and 8 cm at five years, as being ineffective. Table 38 shows that wide spacing has little effect on total volume, but the volume tends to be concentrated on the larger stems, which is desirable. Wide spacing reduces costs of seedlings and planting, but more important it allows a longer period of intercropping which is beneficial both to the plantations and to the farmers.

Table 38—Spacing and growth of *Eucalyptus camaldulensis* at Sagarnath

Spacing (m)	Mean diameter (cm)		Mean annual increment (m ³ ha ⁻¹)	
	Total	Effective	Total	Effective
2 x 2	10.7	11.6	15.8	15.1
3 x 2	9.3	10.5	15.7	14.0
4 x 2	10.8	11.7	15.6	14.9
5 x 2	11.7	12.7	15.8	15.2

For commercial fuelwood production a rotation of five to eight years would be feasible. If the rotation were five or six years no thinning would be needed (though if there were a demand for them ineffective trees could be removed at any time). For longer rotations a thinning at 4–5 years is desirable. On his Site Quality 2, for rotations of ten years, White recommends thinning to 300 stems ha⁻¹ at the age of five; for a 20-year rotation, designed to produce larger material including timber he recommends the following schedule (Table 39).

Table 39—Thinning schedule for *Eucalyptus camaldulensis*

Age (yr)	Trees to be left (stems ha ⁻¹)	Approximate spacing (m)
5	300	6 x 6
10	200	7 x 7
15	100	10 x 10
20	Clear fell	—

Planting in mixture

Some trials of planting *E. camaldulensis* in mixture with other species have been made at Adabhar (R. Shakya, 1990). In 1984, *Cassia siamea* was planted at 3 m x 3 m spacing between *Eucalyptus* at the same spacing, i.e. total initial stocking was 2222 stems ha⁻¹. Fifty per cent of the *Cassia* was cut every winter from the second year onwards. The biomass per tree of the *Cassia* removed in the second cutting was 11.1 kg of wood and 4.2 kg of leaves (air dry weight). At 4.5 years the *Eucalyptus* averaged 10.7 m in height by 6.8 cm in diameter, corresponding to 'poor' in the yield table. This may indicate that the *Cassia* has adverse effects on the *Eucalyptus*. A second trial in the same year used a

number of species, with the same layout for each plot. Available results are as follows (Table 40).

Table 40—*Eucalyptus* growth in mixture with other species

Species mixed with <i>Eucalyptus</i>	Age (months)	<i>Eucalyptus</i>		
		Survival (%)	Height (m)	Diameter (cm)
<i>Cassia siamea</i>	18	96	—	5.3
<i>Leucaena leucocephala</i>	18	96	—	5.8
<i>Dalbergia sissoo</i>	18	88	—	5.9
<i>Acrocarpus fraxinifolius</i>	31	92	9.6	7.7
<i>Acacia catechu</i>	31	92	10.1	8.5
Pure <i>Eucalyptus</i>	31	94	9.8	8.0

These experiments were not replicated. When seen at the age of seven it appeared that the eucalypts were suppressing the *D. sissoo* and *A. catechu*, the *Cassia* was reducing the growth of the eucalypts, and the *Acrocarpus* and eucalypts were of about equal vigour. Trials of mixing *Indigofera teysmannii* with *E. camaldulensis* have also been made. The *Indigofera* suppressed ground vegetation, including *Imperata* grass, very effectively and was estimated to reduce cultivation costs by 50 per cent (Neil, 1990h).

Uses

The timber of mature trees is hard and heavy, with a red heartwood; in Australia it is used mainly for heavy engineering construction, such as for wharves and bridges, and for railway sleepers. In Nepal its main value is for the production of fuelwood and poles, but it has also been tried out successfully for the production of carved furniture. It is a good honey producer. The heartwood of mature trees has a density of 810–1010 kg m⁻³ air dry; according to Hawkins (1987a) the basic density of wood from 2.5-year-old trees is 536 kg m⁻³.

Importance in Nepal

Eucalyptus camaldulensis is eminently suited for large-scale, high-yielding plantations in the Bhabar Terai zone, as has been clearly demonstrated in the Sagarmath Project, where 2700 ha were planted between 1979 and 1987. Individual farmers in this zone usually prefer to plant *Dalbergia sissoo*, but *Euca-*

lyptus still might have a place in small woodlots. Its value in the Middle Hills has still to be established, though of all eucalypts planted in trial plots between 600 and 1600 m it has grown the fastest.

References: The manuals produced by K.J. White for the Sagarnath Project (White, 1986a-f; 1988a-f) are an invaluable source of information on growing *Eucalyptus camaldulensis* in the in the Bhabar Terai zone. Other references, in addition to those quoted in the text, are as follows. M.W. Campbell (1983a); Champion and Brasnett (1958); Lamichhane and Joshi (1980); Letourneux (1957); Magini and Tulstrup (1955); National Academy of Sciences (1980); Streets (1962); Troup (1921); Webb *et al.* (1984).

***Eucalyptus tereticornis* Sm.**

Closely related to *E. camaldulensis*, and mainly distinguished from it by the cap of the bud not being narrowed into a beak.

Origin

This is a species with a very wide range in Australia from southern Victoria to 15°S in Queensland, in a belt along the coast. It also occurs near the south coast of Papua New Guinea. It grows under rainfalls of 500–1500 mm, with a winter, uniform or summer distribution according to latitude. The dry season is variable, up to seven months long, and may be severe in parts of its range. It can experience up to 15 frosts per year, according to locality. With such a wide range of distribution, provenance is important.

Silvicultural characteristics

In Australia it grows to 45 m high, with an erect stem. Its crown is light and narrow, while stem form varies a great deal according to provenance. Although frost occurs in part of its natural range, in plantations it has been found to be frost susceptible, though this presumably depends to some extent on provenance. It is not quite as drought-resistant as some provenances of *E. camaldulensis*. It grows on a variety of soils, but is said not to do well on strongly acid soils. It is relatively fire-resistant. There are 540,000 viable seed kg⁻¹. Sowing rate in seed boxes should be 14 g m⁻². Otherwise nursery and plantation techniques are the same as for *E. camaldulensis*.

Growth rates

Where it has been planted together with *E. camaldulensis*, the latter has usually shown faster rates of growth; however the better *E. tereticornis* provenances compare well with it and have occasionally exceeded it. For instance in one

trial at Adabhar, at the rather young age of 18 months, the Kennedy River provenance of *E. tereticornis* had an estimated MAI eight per cent greater than the Petford provenance of *E. camaldulensis*. The yield table for *E. camaldulensis* could also be used for *E. tereticornis*. Some provenances of *E. tereticornis* have much better form than *E. camaldulensis*, and where production of straight poles is an objective, any slightly poorer growth would be compensated for by this. Outside the Terai, in the early trials between 600 and 1600 m it was second in growth to *E. camaldulensis*, whenever the two species were planted together, but growth was nowhere outstanding. In these trials it did very badly over 1700 m altitude.

Choice of provenances

Many of the most promising provenances come from the Normanby River basin, in northeast Queensland. These include Laura, Kennedy River and Morehead. In general Laura and Kennedy River have produced the highest growth in the Bhabar Terai. Mareeba, from near Cairns, rather further south, is not quite as fast growing but is of very good form. K.J. White (1988b) recommends the following provenances for different types of soil at Sagarnath.

- Well-drained sandy soils
 - First priority: North Lakeland Downs
 - Second priority: Kennedy River; South of Laura; Palmer River
- Silty soils
 - First priority: Morehead River
 - Second priority: North Lakeland Downs
- Silty clay soils
 - First priority: North Lakeland Downs
 - Second priority: 10 km from Mareeba

In India the so-called Mysore hybrid, now believed to be a land race of *E. tereticornis*, is planted on a very large scale, but in all trials in which it has been included in Nepal other provenances have shown superior growth. In addition the Mysore land race is very heterogenous, and trees planted in the same plot show considerable variation not only in height growth but also in leaf size and shape.

Uses

The wood is red, hard and heavy and suitable for heavy construction work. Its density ranges from 730 to 800 kg m⁻³. In India, *E. tereticornis* is being planted on a large scale for pulpwood production. It an excellent source of honey.

Importance in Nepal

It can be regarded as an alternative to *E. camaldulensis* for fuel plantations in the Bhabar Terai. Although provenances of *E. camaldulensis* generally grow rather faster, *E. tereticornis* provenances may turn out to be superior on certain soil types. It also tends to have a better form.

References: Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Magini and Tulstrup (1955); National Academy of Sciences (1983b); Streets (1962); Troup (1921); Webb *et al.* (1984); K.J. White (1988a-f).

Other species of *Eucalyptus* known to have been introduced to Nepal

This list is very incomplete. In particular the results of many trials have not been published, and the final fate of many is unknown. It includes all species known to have been introduced up to the time of writing, even those for which further records are unknown, as it is possible that they may turn up in plantations.

E. alba Reinw. ex Bl. Origin North Australia, Papua New Guinea, Timor, to 6°S; summer rainfall. Tried as a possible alternative to *E. camaldulensis* in the Terai but growth rates much lower. Little further interest. Note: Earlier confused with *E. urophylla*. Much of the very successful '*E. alba*' planted in Brazil and elsewhere was in fact *E. urophylla* or its hybrids.

E. andrewsii Maid. Planted at 1700 and 2000 m in 1976, but height growth poorest of all eucalypts tried.

E. argillacea. Very early trials (seven months) indicated that it might be of value in planting on usar soils in the Nepalgunj area.

E. argophloia Blakely. Introduced 1981. In a later trial at Thulo Sirubari (1400 m) there were no survivors.

E. bancroftii (Maid.) Maid. Tried in 1975 and 1976 at sites ranging from 730 to 2000 m, but out-performed by other species at all sites, and usually of poor form.

E. benthamii Maiden and Cabbage var. *dorrigoensis* Blakely. According to L.D. Pryor there were two good specimen trees at Kakani nursery in 1972. No other records.

E. fastigiata Dean and Maiden. Planted at Chitripani in 1967, but all dead within three years. Pryor in 1972 reported two good specimens at Kakani nursery. Prefers cool areas, but without severe frosts, and not likely to be of great value in Nepal.

E. globulus Labill. subsp. *bicostata* (Maiden et al.) Kirkp. (*E. bicostata* Maiden, Blakely and Simmons). Planted at Chitripani in 1967, with very poor results. If planted at all in Nepal, it should be above 1800 m; it is more tolerant to cold and dry conditions than *E. globulus* subsp. *globulus*, and might be worth further trials at these higher altitudes.

E. globulus Labill. subsp. *globulus*. Origin Tasmania and small area of Victoria, to 38°S; winter to uniform rainfall. Introduced about 1900 into the Kathmandu Valley, where it has reached a fairly large size, but is not physiologically healthy. There have been a number of trials in Nepal, without much success, and it had very poor survival in recent trials in the Middle Hills (Neil, 1989b). This species has proved very valuable in a number of high altitude stations in the tropics, such as the Nilgiri Mountains in southern India and in Ethiopia, but usually in areas with relatively mild winter climates (mean temperatures of coldest month 9–14°C). In general the climate in Nepal seems to be too harsh for it to grow well; subsp. *bicostata* might be more promising.

E. globulus Labill. subsp. *maidenii* (F. Muell.) Kirkp. (*E. maidenii* F. Muell.). Origin southern New South Wales and northeast Victoria, to 34°S; winter to uniform rainfall. Tried at a number of sites by the Nepal–Australia Forestry Project in 1973–76. At altitudes over 1700 m it was among the eucalypts showing the best rates of growth; aged seven years at Lower Nagarkot (1700 m) it had 72 per cent survivors, and a mean height of 4.6 m, while at Upper Nagarkot (2000 m) survivors were 92 per cent and mean heights 5.9 m. These growth rates are very poor compared with those of eucalypts in the Terai, but reasonably good in comparison with other species at these altitudes, especially considering the less than optimum conditions of these trials. At Pakhribas, however, growth and form were poor. If eucalypts are to be planted above 1500 m altitude this is one of the species worth trying. Seed 110,000 kg⁻¹. Wood density 650–900 kg m⁻³.

E. grandis Hill ex Maiden

Bark in various shades of grey, shed in long strips; a 'stocking' of darker rough bark, 1.2–2 m long at the base of the stem. Leaves 10–20 cm by 2–4 cm, lanceolate, glossy dark green above. Flowers 7–12 together in umbels on

flattened stalks. Fruit about 8 mm by 6 mm, pear-shaped, on very short stalks. It is native to coastal areas of northern New South Wales and southern Queensland, with two outliers in central and northern Queensland, and grows under summer rainfalls of between 1000 and 1750 mm, with a dry season of about three months. In parts of its range there are occasional frosts.

This is a species which has been very successful and high yielding in other parts of the tropics, including areas with a marked summer dry season, such as Zambia. It has done best at altitudes of between 800 and 1800 m, the upper limit being governed by the incidence of severe frost (it will tolerate light frosts). Where it thrives yields can be very high, up to about $45 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1}$; this is in clean-weeded plantations. It somewhat less drought-tolerant than *E. camaldulensis*, and is more exacting in its soil requirements, needing a deep, free-draining soil, at least 1 m deep if this is a fertile loam, but 2 m or more on less fertile sandy soils.

It was introduced into Nepal about 1960. Unfortunately its performance at low altitudes has on the whole been disappointing, with a rather poor survival rate and indifferent growth. The best result was at Chitripani (480 m), where in a plot 4.5 years old there were 80 per cent survivors with a mean height of 11.1 m, and breast height diameter of 10.5 cm. Even this is only equivalent to site quality 'poor' on the *E. camaldulensis* yield table.

At altitudes of over 1600 m it was generally the best species in the Nepal-Australian trials between 1973 and 1975; at Lower Nagarkot (1700 m) seven years after planting there were 74 per cent survivors with a mean diameter of 6.0 cm, and at Upper Nagarkot (2000 m) at the same age there were 98 per cent survivors with a mean diameter of 7.6 cm. At Pakhribas (1450 m) the provenance from Mount George, New South Wales, had at 3 years old 100 per cent survivors with a mean height of 5.4 m. If it has a future at all in Nepal it will be at altitudes of between 1500 and 2000 m, on sites not subject to severe frosts.

630,000 viable seed kg^{-1} . It has a lighter timber than that of *E. camaldulensis*, with a density of 580–640 kg m^{-3} . Very fast-grown timber is very liable to warp and split, but in some countries it is used on a fairly large scale for fruit boxes. It produces good straight poles, but there are difficulties in preservative treatment.

References: Pande (1978); Pande and Jain (1976).

E. gunnii Hook f. Introduced 1983; no further details. Mainly valuable as an ornamental; is frost-resistant and does well in temperate climates, such as England, and hence probably climatically unsuited to Nepal except at high altitudes.

E. houseana W.V. Fitzg. ex Maiden. Grows naturally on alluvial flats and swampy area in West Australia. Introduced to Chitripani in 1980, but no further records seen. Ornamental.

E. johnstonii Maiden. Introduced 1983, and seedlings raised in Chalnakhel nursery in 1984. Failed at Kharidunga (2400 m) in 1984.

E. leucoxylon F. Muell. Tried in the Trisuli Watershed Project, 1967, but failed for lack of fencing. Not likely to be of much value.

E. longifolia Link and Otto. Origin southeast New South Wales to 33°S; winter to uniform rainfall. Introduced about 1900 and has grown to a large size as a roadside tree; as far as is known not tried in plantations.

E. macarthurii Deane and Maiden. Planted 1974 and 1975 by the Nepal–Australian Forestry Project, on four sites between 1450 and 2000 m, but relatively poor growth on all sites.

E. maculata Hook. f. Planted at Chitripani, 1980, and at Bardia, 1975, where after six months survival was 38 per cent and height 66 cm; no more information available. Has grown well at Tansen (Gijsberg, pers. comm.). Closely related to *E. citriodora* but less drought-tolerant.

E. mannifera Mudie. Ornamental only. Planted at Chitripani, 1967, but none survived three years.

E. melanophloia F. Muell. Planted at Bardia in 1977, no further information.

E. microcorys F. Muell. Planted at Pharping, 1973; at 4.5 years reached 3.6 m in height, outgrown by several other species.

***E. microtheca* F. Muell.**

(Syn. *E. coolabah* Blakely and Jacobs).

The coolabah tree of the song. Origin inland mid-northern and northern Australia, in summer rainfall, often in semi-desert conditions, but generally near billabongs and other water courses. Drought-tolerant and will grow on heavy soils with a high pH. Planted at Bardia, 1977; Chitripani, 1980; Adhabar, 1982. At Adhabar it was quite healthy, but the growth rates were poor and the stem crooked, which is characteristic for the species. It should generally be planted only on sites which are so difficult that nothing better can be grown. According

to White (1988g) very young trials (seven months) showed promise on usar soils near Nepalganj. 420,000 seeds kg⁻¹.

E. muelleriana Hewitt. Planted at Chitripani in 1967, but all dead within three years. Climatically unsuited.

E. nitens (Deane and Maiden) Maiden. Origin above 1000 m, in Victoria and New South Wales, up to 30°S. Winter to uniform rainfall, frost-resistant. Failed at Chitripani, but did moderately well at Pakhribas, where growth was comparable to *E. grandis*. Good form. Only likely to succeed at higher elevations, if at all.

E. nova-anglica Deane and Maiden. Introduced about 1960; some satisfactory trees near Kakani (Pryor, pers. comm.). Included in the Nepal–Australia trials at a number of sites above 1400 m, and at Pakhribas, but with generally poor results, best being at Lower Nagarkot where there were 68 per cent survivors with a mean diameter of 7.4 cm after seven years. A relatively low-growing heavily branched tree, valued in Australia mainly for shade and shelter, and unlikely to be of much value in Nepal.

E. obliqua L'Herit. Planted in Chitripani, 1967, but all dead after about three years. Climatically unsuited to Nepal.

E. paniculata Sm. Origin eastern New South Wales, to 30°S; uniform to summer rainfall. Planted in Chitripani in 1967; 29 per cent survived for three years, and a few fairly good trees were alive after 13 years.

E. pellita F. Muell. Origin New South Wales to northern Queensland, to 12°S; uniform to summer rainfall. Planted at Chitripani, 1980, and at Adabhar, 1988, where after 2.5 years there were 89 per cent survivors with a mean height 4.4 m and a mean breast height diameter 3.2 cm, much inferior to species such as *E. camaldulensis*.

E. propinqua Deane and Maiden. Origin northern New South Wales to southern Queensland to 24°S; summer rainfall. Introduced about 1900 to the Kathmandu Valley and has reached a large size (up to 33 m in height) as a roadside tree (Pryor, pers. comm.). Planted at Sagarnath, 1980; results unknown. Might grow quite well at lower altitudes, but other species are likely to give higher yields.

E. punctata DC. Origin New South Wales to central Queensland, to 25°S; uniform to summer rainfall. Planted at Chitripani, 1980, with unknown results.

Rather similar in its requirements to *E. propinqua*, which is a better timber and would generally be preferred.

E. quadrangulata Deane and Maiden. Introduced about 1900 into Kathmandu Valley where there are some large roadside trees (Pryor, pers. comm.). Otherwise little known in cultivation.

E. resinifera Sm. In trial at Adabhar, 1984. At two years old 46 per cent survivors; mean height 4.1 m. The least successful species in this trial.

E. robusta Sm. Origin coastal New South Wales and southern Queensland to 23°S; uniform to summer rainfall. In nature it grows in swamps and valley bottoms, but when free from competition by other *Eucalyptus* species it will grow on higher ground at a faster rate than in the swamps. Introduced about 1900 into the Kathmandu Valley, where numerous examples of large roadside trees are to be seen, with fibrous, ridged bark and glossy green leaves. Later roadside and similar plantings took place about 1960. It has not, however, done very well in trials; it failed at Ranipawa (1350–1500 m), and at Thankot (1650 m).

E. rubida Deane and Maiden. Planted at Chitripani, 1967; only two per cent survived three years, but one or two of these still survived after 13 years. In Australia mainly valued for shelter.

E. saligna Sm. Very similar to *E. grandis*, but dark 'stocking' at base of stem less pronounced, more flowers (7–12) per umbel, and fruit cylindrical or bell-shaped, on stalks 5–8 mm long. Often confused with *E. grandis* in the past. It occurs in a belt along the coast of New South Wales and southern Queensland, under conditions of uniform to summer rainfall of between 800 and 1200 mm, with a not very severe dry season of about four months. There are 5–15 frosts per year, and in parts of its range occasional falls of snow may occur. It can resist temperatures down to about -7°C. Its best development is on rather heavy but fertile soils. Viable seed kg^{-1} : 560,000. Sowing rate in seed trays: 14 g m^{-2} . It was introduced into the Kathmandu Valley about 1900 and some trees have now reached a height of about 40 m. At Lower Nagarkot (1700 m) the Casino provenance reached 12 cm in diameter at seven years, being the best species at this site. Growth at Upper Nagarkot (2000 m), however, was much poorer. It is largely an unproven species, but it shows some promise between 1500 and 2000 m. In Nepal the provenance from Casino, New South Wales, has grown better than other provenances (Glen Innes and Kangaroo Valley). In general it has a slower rate of growth than *E. grandis*. The wood is hard, red or pink, with a density of 730–1010 kg m^{-3} .

E. sideroxylon A. Cunn. ex Wools. Planted at Devighat, 1968, but fate unknown.

E. smithii R.T. Baker. Introduced about 1958–60, round Thankot. Short-boled. Unlikely to be of importance in Nepal.

E. stellulata Sieb. Origin Victoria to northern New South Wales to 29.5°S; uniform to summer rainfall. Planted at Chitripani, where 38 per cent survived three years, and were still healthy after 13 years. Failed at Thulo Sirubari (1400 m). A spreading tree to 15 m high; frost-resistant.

E. tessellaris F. Muell. Origin northern New South Wales, and Queensland to 16°S; summer rainfall. Planted at Chitripani in 1980; results unknown. Can withstand a severe dry season, but is slow growing and unlikely to be of importance in Nepal.

E. torelliana F. Muell. Leaves broad, slightly peltate; leaf stalks bristly. Flowers numerous, in dense clusters. Origin Queensland to 16°S; summer rainfall. Planted in 1980 at Chitripani, and lost sight of, but in 1992 was the most vigorous survivor in this trial. Casts a dense shade, and will shade out grass and undergrowth, but growth is fairly slow when compared with species such as *E. grandis* and *E. camaldulensis*. Has some possibilities as a firebreak. Only slightly frost-tolerant. Hybridizes with *E. citriodora*. 260,000 seeds kg⁻¹.

E. urnigera Hook. f. Origin southeastern Tasmania, to 42.5°S; winter rainfall. Said to be very frost-resistant. Introduced in 1983, and seedlings raised in 1984 in Chalnakhel nursery. Failed at Kharidunga (2400 m) and later trials in 1988 either failed completely or had very poor survival. Unpromising.

E. urophylla S. T. Blake.

Origin Timor, and other eastern Indonesian Islands to 8°S. This is the species that was widely planted in Brazil as *E. alba*, and which has been found to be a very fast-growing species in various tropical countries. It has been included in trials at Adabhar where its rates of growth have been comparable with but generally slightly slower than those of *E. camaldulensis*, as shown in the following table (Table 41, page 538). It has a good form and a deeper crown than *E. camaldulensis*, and retains its lower branches more. This is likely to reduce grass competition, but may also reduce the time during which cultivation of crops between the trees is possible. It is more susceptible to damage from winter chill. There is considerable difference in growth of different provenances, and more provenance trials would be desirable, with the objective

of testing it as a possible alternative to *E. camaldulensis* for large-scale fuel-wood plantations in the Terai.

Table 41—Growth of *Eucalyptus urophylla* compared to *Eucalyptus camaldulensis*

Trial no.	Age (mon)	Species	Provenance	Survival (%)	Height (m)	Diameter (cm)
1/82	43	<i>E.urophylla</i>	Mt Mandiri, Indonesia	95	—	7.9
		<i>E.camaldulensis</i>	Petford	94	—	8.0
26/84	18	<i>E.urophylla</i>	Mt Mandiri, Indonesia	94	5.7	4.3
		<i>E.camaldulensis</i>	Petford	96	6.4	4.8
(Neil, 1989h)	42	<i>E.urophylla</i>	Mt Mandiri, Indonesia	—	10.0	7.6
		<i>E.camaldulensis</i>	Petford	—	12.1	8.0
88/14	30	<i>E.urophylla</i>	Mt Egon, Indonesia	81	7.5	5.0
		<i>E.urophylla</i>	Mt Lewotob, Indonesia	57	7.5	5.0
		<i>E.urophylla</i>	West Timor	83	5.5	4.8
		<i>E.camaldulensis</i>	Emu Creek	96	8.2	5.3

Notes: In trial 88/14 most of the deaths were due to termite attack, although aldrin was used to protect the seedlings.

References: National Academy of Sciences (1983b); Webb *et al.* (1984).

E. viminalis Labill. Origin Victoria to southern Queensland. Introduced about 1900 into Kathmandu Valley, where large roadside trees have been established. Planted at Chitripani in 1967; 6 per cent survived three years, but all were dead by 1980. At Pharping planted 1973, reached a height of 6.3 m at 4.5 years, the best growth at that site, and at other trials the odd 'stray' tree of this species, perhaps planted by error, has shown good growth. At both Lower and Upper Nagarkot, however, growth has been poor. Perhaps worth consideration if it is ever proposed to resume trials of *Eucalyptus* between 1000 and 1500 m. Frost-resistant.

General references: The FAO Forestry Series No. 11 *Eucalyptus for Planting* based on the work of M.R. Jacobs (1979), is the standard text book on eucalypt plantation practices and has been drawn on to a considerable extent. Penfold and Willis (1976) has been used for certain species which are not included in Jacobs. Blakely (1955) though somewhat out of date, is the only publication giving botanical descriptions for the whole genus (apart from a few species described since it was published). *Forest Trees of Australia*, published by the Forestry and Timber Bureau gives descriptions, well illustrated by the photographs, of 65 species including most of those in common cultivation in plantations. Jacobs (1955) describes eucalypt growth patterns. See also Anon. (1981a); Fearnside (1975); Mather (1974); Neil (1989b).

Eurya Thunb.

Theaceae

Trees or shrubs. Leaves alternate, margins with fine, closely spaced teeth. Flowers in clusters of 2–4 in the leaf axils, and along the twigs, unisexual. Stamens 5–15, joined to base of petals. Ovary three-celled. Fruit spherical, fleshy and berry like.

Eurya acuminata DC.

(Syn. *E. japonica* auct. non Thunb.)

Nepali: jhingane, tingare, sano jhyanua, jhikune pate, tinger, thyasu.

Sherpa: pajan.

Tamang: tengar.

Leaves with teeth along at least half of leaf margin; leaf stalks 2–3 mm long; flowers 5–8 mm across; stamens about 15; fruit 5 mm diameter, dark blue or purple. This small tree occurs in Nepal between 1300 and 2700 m, in a variety of vegetational associations. It resists frost and drought, and will grow on comparatively poor soils. The berries, which are blue when ripe, can be collected between November and February. After removal of the pulp they should be sown immediately, as the seed has short viability. It is a fodder species, but not one of the most highly rated ones; its leaves contain about seven per cent crude protein. They are mainly fed to sheep and goats. In Sikkim the tree is pollarded and the leaves used for compost. Its wood is a good fuel; it weighs about 700 kg m⁻³.

***Eurya cerasifolia* (D. Don) Kobuski**

(Syn. *E. symplocina* Blume)

Nepali: jhingane, thulo jhyanu, jhikaune pate.

Leaves with teeth near the apex only, and some leaves without teeth; flowers about 6 mm across; fruit blue-black, about 5 mm diameter. This species is found in Nepal between 900 and 2300 m and is often associated with *E. acuminata*. Both species appear after protection of degraded woodland. The fruits ripen in May and June, and as the seed has short viability it should be sown immediately after collection. It is regarded as a rather poor fodder, but a good fuel; the wood weighs about 600 kg m⁻³. Its growth is very slow; natural trees 26 years old averaged about 6 m in height by 10 cm in diameter (Levenson, 1979).

References: M.W. Campbell (1983a); Levenson (1979); Panday (1982).

***Exbucklandia* R. W. Brown**

Hamamelidaceae

***Exbucklandia populnea* (R. Br. ex Griffith) R.W. Brown**

(Syn. *Bucklandia populnea* R. Br. ex. Griffith)

Nepali: pipila.

Large tree. Leaves leathery, broadly ovate, with 5–7 veins radiating from base, not toothed, usually hairless. Flowers in spherical heads, female heads 8–10 mm, bisexual 15–20 mm in diameter, with protruding cream-white stamens. Fruits in globose woody heads of 5–12 capsules.

Natural occurrence

It is found between 1300 and 2100 m in Nepal. It is predominantly an eastern species, but occurs at least as far west as the longitude of Kathmandu. Outside Nepal it is common in the Darjeeling area of West Bengal, and extends eastwards to southern China, and southwards to Indonesia.

Silvicultural characteristics

A large shade-bearing evergreen tree. It is very susceptible to differences in altitude, aspect and rainfall, and does best around 1500 m. The seedlings suffer from frost and cold winds and are subject to browsing by cattle and deer.

Nursery and plantation techniques

In India the tree flowers and fruits all the year round, but the seed is usually collected in December to January, or March. There are about 200,000 seeds kg^{-1} ; and 1 kg of fruit will produce about 125 g of seed. The seed can be stored for a year. Laboratory tests in Kathmandu gave 19 per cent germination, though in India up to 75 per cent has been recorded. There germination is said to take 2–4 weeks, but in cold weather up to ten weeks may be needed. The seed should be sown in trays or in shaded beds at the rate of about 100 g m^{-2} . The young seedlings are pricked out into polypots when four true leaves have appeared. In West Bengal the seedlings are kept in the nursery for 15 months at lower elevations, and a year more at high elevations. At Chalnakhel (1280 m) seedlings raised in polypots from seed sown in November were less than 4 cm tall in June of the following year, indicating that at least a year will be needed in the nursery. Because of its liability to frost damage *Exbucklandia* is planted in India in alternate line mixture with *Alnus nepalensis* or *Cryptomeria japonica*.

Rate of growth

Sample plot data from Darjeeling, quoted in Ghosh (1977), give a mean height of 11.3 m and a mean diameter of 13.2 cm at 19 years old; and a height and diameter of 24.7 m and 25.4 cm respectively at 40 years old. The mean annual volume increment, including thinnings, was about $13 \text{ m}^3 \text{ ha}^{-1}$, which is moderately good.

Uses

It produces a valuable timber, much used in the Darjeeling area for planking, doors and window frames. It weighs about 730 kg m^{-3} .

Importance in Nepal

The only records of its use in plantations are in Ilam District, where it is reported to be popular. Its survival when planted by farmers was 82 per cent, the best of any species, but in plantations only 11 per cent survived, the remainder having been killed by frost (Olsson, 1983).

References: Ghosh (1977); Suri and Seth (1959).

Ficus L.

Moraceae

Fig

General

There are about 34 species of *Ficus* in Nepal, of which 27 are small or large trees. They are important mainly as a source of fodder and include some of the most widely used fodder trees in the country. Some are also valued for their edible figs; others are sacred trees, and are commonly planted as shade in *chautara* (raised platforms, used as halting and resting places). The wood of most species is soft, white, and not durable and is little used either for timber or fuelwood.

The flowers of *Ficus* species are borne in hollow fleshy receptacles, with an opening at the apex. Within the receptacles the flowers are of three or four types: male, female and neuter or non-functional female, plus sometimes pseudo-hermaphrodite flowers, which are male flowers with rudimentary ovaries. The flowers are pollinated by very small gall-wasps, which lay their eggs in the neuter flowers, which turn into galls; from these 'gall-flowers' the insects eventually hatch out, mate, and pollinate the female flowers. In one section of the genus (section *Urostigma*), male, female, and gall-flowers are found within the same receptacle; this section includes *Ficus benghalensis* (bar), *F. glaberrima* (pakhure), *F. lacor* (kabro) and *F. religiosa* (pipal). Other figs however have the male and gall flowers in one set of receptacles, and the female flowers which produce seed in another set. These usually occur in different trees. Thus in collecting seeds of figs it is important to select the receptacles which have female flowers, as these alone will produce fertile seed. The gall-flowers can be recognized by opening the 'seed'; in place of the embryo a small white grub will be found (Brandis, 1921).

A number of *Ficus* species often begin life as epiphytes. The seeds are carried by birds to the forks of the branches of other trees, or to crevices in buildings, from which they send down aerial roots to the ground. If they are epiphytic on trees they may eventually surround the tree with aerial roots, and kill it. Such figs are known as strangler figs; they are common in wet evergreen forests, but are relatively rare in Nepal. Most epiphytic figs can also establish themselves in the normal way by the seedlings germinating on the ground. Species in Nepal which are reported to be at least occasionally epiphytic are *F. benghalensis*, *F. glaberrima*, *F. lacor* and *F. religiosa*.

Nursery techniques

The seeds of figs are very small, with between one and eight million seeds kg^{-1} . They can be extracted from the receptacles by squeezing the fleshy contents, excluding the skin, into a bucket of water, mixing well, and allowing the seed to settle to the bottom. The water is changed, and the process repeated until all the seeds have been separated (Kessler, 1981). The seed should be well dried before storage; seed of most species will keep its viability for at least a year, if kept in sealed containers.

The small seeds dry out very rapidly, so continuous humidity is necessary to ensure germination. They should be sown, preferably in trays, otherwise in beds, containing a free-draining sandy loam soil mixture; this should not contain organic material, as small fig seedlings are very subject to damping-off. The surface of the tray or bed should be very carefully levelled. The sowing rate should be about 70,000 seeds m^{-2} , and after the seed has been sown it should be covered with a thin layer of fine sand. It is best to raise the seedlings in trays and water from below; if beds are used they should be well watered after the seed has been sown, using a fine-rosed watering can. Trays or beds should have a shade placed over them about 15 cm above the surface. Once the seeds have germinated the shade should be raised to about 50 cm. The surface of the bed or tray should be kept moist, but not wet, by frequent light watering.

The seedlings should be pricked out into polypots when they have at least three and not more than five leaves apart from the cotyledons, which will usually be 4–5 weeks after germination begins. They should be kept under shade for another week or ten days, after which the shade is gradually reduced, until after three weeks to six weeks in all it has been completely removed.

In the Terai the seed should be sown in January or February, and the pricking out completed by mid-March. Above 700 m and on cold sites sowing should be in early August, and pricking out finished by mid-September, while at altitudes over 1500 m sowing in April, for planting 16 months later, may be needed. Use of rather large polypots, 10 cm x 18 cm lay-flat, with 20 per cent compost in the potting mixture is desirable. Spacing and regular root pruning is important especially during May and June when the seedlings grow very fast.

Kessler (1981) reports success from direct sowing the seed into polypots, at 5–10 seeds per polypot. The plants should be kept under shade for about three months, and the seedlings thinned out to one per polypot after two or three months. Many figs can also be easily raised from cuttings, and this is the method normally used by local farmers. Farmers usually use large branch cuttings up to two metres long and about 5 cm in diameter, but hardwood cuttings taken in the dormant season when the trees are leafless are more transportable, and probably give a higher percentage of success. Cuttings

should be 1–2 cm in diameter, and 25–30 cm long, and placed in soil in polypots with about 10 cm of the stem buried. They should be kept under shade until the rains. Shoots appear after four weeks but roots take longer. Plants from cuttings taken in February can be planted in the monsoon. Cuttings can also be raised in beds, and later transplanted into polypots. Air layering has been used successfully for *F. glaberrima* and some other species; for the technique see *F. glaberrima*. All *Ficus* species are liable to damage by browsing and need to be well protected against domestic animals.

Key to *Ficus* in Nepal

Adapted from Grierson and Long (1983). An asterisk (*) after the name indicates that the species is dealt with in more detail later.

- (1) Leaves opposite, broadly ovate, 13–40 cm long, sometimes lobed, rough above, hairy beneath, margins toothed; figs 2–4.5 cm in diameter, covered in brown hairs *F. hispida**
- (1) Leaves alternate 2
- (2) Base of leaves strongly unequal sided; figs 1.5–2 cm in diameter, on long leafless shoots, those near to the base reaching to ground level and burying figs *F. semicordata**
- (2) Base of leaves equal sided or almost so 3
- (3) Figs mostly borne on scaly leafless branches on trunk or main branches ... 4
- (3) Figs in axils of leaves, or on previous year's growth below current year's growth of leaves, on young branches 6
- (4) Leaves hairless on under side, 6–15 cm by 3–7 cm, margins entire; figs 2–3 cm across, borne on somewhat slender shoots 8–17 cm long *F. racemosa* L. (syn *F. glomerata* Roxb. Nepali: dumri, gular)
- (4) Leaves hairy on under side 5
- (5) Leaves five-veined at base, 15–30 cm by 10–25 cm; figs 2.5–5 cm long by 5–7.5 cm broad, top-shaped, strongly ribbed, russet-brown tinged with red or purple when ripe *F. auriculata**
- (5) Leaves three-veined at base, 10–20 cm by 8–19 cm; figs 3.5–4 cm by 2.5–3 cm, obovoid, apex flattened, red when ripe *F. oligodon* Miq.
- (6) Leaf margins with regular fine teeth; leaves sometimes deeply lobed, rough above, hairy beneath 7
- (6) Leaf margins entire or with a few blunt teeth near apex; leaves unlobed ... 8

- (7) Leaves 7.5–12 cm long; figs solitary, stalked, rounded or top-shaped, 1.2–2.5 cm, yellow when ripe; western species *F. palmata* Forsk.
- (7) Leaves 20–40 cm long; figs in pairs, sessile, ovoid or globose, 2–4.5 cm, covered in brown hairs; eastern species *F. hirta* Vahl
- (8) Figs without stalks, or stalks less than 3 mm long, (occasionally up to 5 mm in *F. neriifolia*) 9
- (8) Figs on stalks 5–20 mm long (occasionally as small as to 3 mm in *F. subincisa*) 24
- (9) Leaves broadly ovate or almost triangular, broadest at base, apex prolonged into a long fine point 10
- (9) Leaves ovate, elliptic, or obovate, broadest near or above middle 12
- (10) Base of leaf notched or cordate, never narrowing to petiole; tail at apex of leaf 4–25 mm long; figs 6–8 mm across, purple with green dots when ripe.....
..... *F. arnottiana* (Miq.) Miq.
- (10) Base of leaf broadly rounded or truncate; figs 12 mm across 11
- (11) Tail of leaf 2.5–8 cm long, about one third as long as blade; secondary veins 6–8 pairs; figs dark purple when ripe *F. religiosa**
- (11) Tail of leaf 1.2–2.5 cm long, about one sixth as long as blade; secondary veins 3–6 pairs; figs nearly black when ripe
..... *F. rumphii* Blume (Nepali: pakar)
- (12) Lateral veins indistinct, close, parallel, numerous; leaves often leathery and shiny..... 13
- (12) Lateral veins distinct, 5–11 pairs 16
- (13) Stipules large and conspicuous, 10–20 cm long; leaves 11–33 cm by 5–15 cm, apex pointed, base rounded or cuneate, leaf stalks 2–7 cm long; figs oblong-ellipsoid, 10–1 mm by 5–7 mm, sessile *F. elastica* Hornemann
- (13) Stipules inconspicuous, less than 2 cm long 14
- (14) Apex of leaf rounded; leaves obovate, leathery, base cuneate; figs spherical, 10–16 cm, yellowish when ripe *F. curtipes* Corner
- (14) Apex of leaf with blunt or sharp point 15
- (15) Apex of leaf abruptly narrowed into point; leaf not three-veined at base; no aerial roots. Leaves 6–12 cm by 4–6 cm, ovate elliptic, figs 2 cm in diameter, orange when ripe *F. benjamina* L.

- (15) Apex of leaf with short blunt point; leaf strongly three-veined at base; branches with aerial roots. Leaves 4–8 cm by 3–6 cm, elliptic-obovate; figs 0.8–1 cm in diameter, black when ripe *F. microcarpa* L.f.
- (16) Leaves membranous, more than twice as long as broad, lanceolate, oblanceolate, ovate-elliptic or oblong, mostly 3–8 cm broad; figs 5–15 mm 17
- (16) Leaves coriaceous, less than twice as long as broad, ovate or broadly elliptic, mostly 7–18 cm broad; figs 15–25 mm 19
- (17) Figs 12–15 mm in diameter, purplish when ripe; leaves elliptic-oblong, 11–17 cm by 4–7 cm, abruptly narrowed to a point, three-veined at base; leaf stalks 3–8 cm long, jointed at apex; branchlets usually densely hairy *F. lacor* *
- (17) Figs 5–8 mm in diameter; leaves oblanceolate to elliptic-lanceolate 18
- (18) Leaves gradually tapering to a point; veins 10–12 pairs; leaf stalks 1–2 cm, smooth; figs 5–8 mm; branchlets reddish *F. neriifolia* *
- (18) Leaves abruptly tapering to a point; veins 5–7 pairs; leaf stalks 0.5 cm long, scurfy; figs 6–7 mm in diameter, orange-red when mature; branchlets greenish-brown *F. subulata* Bl.
- (19) Leaves rather sharply narrowed into point 1–2 cm long; lateral veins 8–13 pairs 20
- (19) Leaves obtuse or with a blunt point up to 5 mm long; lateral veins 5–8 pairs 21
- (20) Branchlets and undersides of leaves usually hairless; leaves 12–22 cm by 7–13 cm, 5–7-veined at base; leaf-stalks 1–3 cm; figs 2–2.5 cm long, orange-red when ripe *F. drupacea* Thunberg
- (20) Branchlets and undersides of leaves usually hairy; leaves 8–15 cm by 6–10 cm, three-veined at base; leaf stalks 6–10 cm; figs 6–8 mm, reddish and warty when ripe *F. geniculata* Kurz
- (21) Aerial roots present; leaves 9–21 cm by 8–16 cm, ovate, apex rounded or with a blunt point, smooth and shining above; lateral veins 5–6 pairs; 5–7-veined at base; leaf stalks 1.5–6 cm; figs 1.5–2 cm in diameter..... *F. benghalensis* *
- (22) Aerial roots few or none 23
- (23) Leaf stalks 1.5–6 cm; leaves 10–15 cm by 6–10 cm, usually three-veined at base; figs 1.5–2 cm in diameter, when young enclosed by a deciduous sheath, when ripe with 3 bracts 2–3 mm long at base *F. altissima* Bl.

- (23) Leaf stalks 6–11 cm long; leaves 12–25 cm by 10–18 cm, three-veined at base; figs ovoid, depressed at apex, 1.5–2.5 cm in diameter, lower third enclosed by a cup formed from the fused bracts *F. hookeriana* Corner
- (24) Stalks of figs with scale-like bracts only at or near base; or stalks rough with no bracts 25
- (24) Stalks of figs with scale-like bracts above middle or at apex (sometimes only scars of fallen bracts to be seen) 26
- (25) Leaves elliptic or rhombic, 9–15 cm by 3–8 cm, abruptly narrowed into a point 5–10 mm long at apex, slightly rough beneath; lateral veins 5–7 pairs; leaf stalks 0.5–1 cm long. Figs 5–8 mm, rough to touch *F. tinctoria* Forst.f.
- (25) Leaves oblong-elliptic, up to 20 cm by 8 cm, narrowed into a point 10–15 cm long, smooth beneath; lateral veins 8–12 pairs; leaf stalks 1–2.2 cm long. Figs 1.5 cm, smooth *F. nervosa* Roth
- (26) Figs obovoid, narrowed to base, 10–20 mm by 10–15 mm, yellow when ripe; leaves usually with several coarse teeth at apex, narrowing into a tail 1.5–2.5 cm long *F. subincisa**
- (26) Figs subglobose, rounded at base; leaves entire, or shallowly sinuate-dentate; leaves pointed or with a short tail at apex 27
- (27) Leaves ovate, 10–16 cm by 7–14 cm, margin entire or shallowly sinuate-dentate at apex; lateral veins 4–5 pairs; leaf stalks 2–6 cm. Figs subglobose, 1.5–3 cm *F. laevis* Bl.
- (27) Leaves ovate-elliptic, 8–20 by 3–9 cm, margin entire; lateral veins 7–10 pairs; leaf stalks 2–3 cm. Figs globose, 6–7 mm, orange *F. glaberrima**

Ficus abelii Miq. and *F. squamosa* Roxb. are small shrubs. *F. hederacea* Roxb., *F. heterophylla* L.f., *F. pubigera* (Wall. ex Miq.) Brandis, *F. pumila* L., and *F. sarmentosa* Buch.-Ham. ex Sm. are climbers usually rooting at the nodes. *Ficus carica* L., the cultivated fig, is sometimes planted for its fruit. Nepali: anjir.

***Ficus auriculata* Lour.**

(Syn. *F. roxburghii* Wall. ex Miq.)

Nepali: nebharo, nimmaro, timilo hareto, khamare, anjir.

Silvicultural characteristics

It is a medium-sized tree which is widely used for fodder in all regions of Nepal, and which grows up to about 2000 m. It is a strong light-demander. The seedlings are rather frost-tender; when they were planted on an exposed slope at 1900 m at Pakhribas, about 33 per cent died, and the tops of all the survivors were killed by cold and frost. Such trees will usually recover however. The trees may be killed even by light fires. They pollard and coppice well.

Artificial regeneration

The figs, which grow in clusters from the trunk and larger branches, ripen between June and September, but usually in July–August. Fertile figs, producing seed, and gall figs occur on different trees. There are 3–8 million seeds kg^{-1} . The dried seed should be stored in sealed containers. Germination takes from ten days to eight weeks. Below 700 m the seed should be sown in early to mid-February, to provide plantable seedlings by the monsoon. Above 700 m sowing in early August will provide plants for the next monsoon.

Burslem (1988; 1989a) has carried out experiments on germination of the seed. He found that germination was equally good whether the material in the seed trays was soil, sand, or a mixture of the two, but that best results were obtained by covering the seed, after sowing, with fine sand (rather than coarse sand or soil), very lightly, so that some of the seed were still visible through the sand. Watering from below gave considerably better results than watering with a local watering can with large holes in the rose.

Sowing should be designed to produce a seedling density of about 20,000 m^{-2} ; 4–5 g of seed m^{-2} will normally give this. Before 1985 the best community nursery sending in returns produced the equivalent of 360,000 plants kg^{-1} of seed, equivalent to about eight per cent germination, but the median was much lower, only about 10,000 plants kg^{-1} . Laboratory germination can be as high as 95 per cent, and in research nurseries 45–75 per cent germination has been achieved when appropriate techniques were used. It is clear that techniques in many nurseries leave much to be desired. Heavy mortality of seedlings after germination was reported from several nurseries, up to 47 per cent in one case; this was largely due to damping-off.

Propagation by hardwood cuttings has given varying results. At Hetauda cuttings produced buds and leaves, but no roots, and at Chalnakel only 12 per cent rooted. However at Lumle 87 per cent of cuttings taken in the last week in

March rooted ; these were 30–45 cm long, set in a bed containing 40 per cent compost and 60 per cent forest soil, mulched with *Schima-Castanopsis* litter, and under partial shade (Napier, 1988). Parajuli (1988) also obtained 77 per cent and 86 per cent rooting from cuttings taken in February and March respectively. Thus success from cuttings can be obtained, and it is certainly worth continuing trials on factors influencing rooting.

Performance in plantations and rate of growth

Survival and growth in plantations have been very variable. At Tistung (1900 m) up to 1985 trials of planting in the open failed completely. In a later trial there, 50 per cent of the plants survived when planted in the open without fertilizer, but the survival was 87 per cent when the plants were given half a *pathi* (2.2 l) of compost each, and also when they were planted under the shade of pines, with or without compost. In another trial at Tistung after six months, survival in the open was 75 per cent, under pines was 100 per cent.

There were also responses to fertilizer in trials planted in 1985 at Irkhu, Melechaur and Sangachowk in Sindhupalchok District. Here all the figs were planted under pine of different ages and the fertilizer used was 50 g of Complexol (20:20:0) per tree. At Sangachowk, under four-year-old pine, fertilized plants had 70 per cent survival after 28 months, unfertilized none; in the other two trials fertilizer increased height growth by 44 and 67 per cent respectively, though even with fertilizer the best mean height growth was only 50 cm, which is far from outstanding. There is a possibility that though the shelter of pine trees may assist *F. auriculata* to become established, growth may later be suppressed, and gradual opening of the pine canopy may be needed.

Experiments at Pakhribas (1700 m) have been reported by L. Joshi and Sherpa (1992). One, on date of planting, gave 100 per cent survival after one year for seedlings planted in May, June, August and September, 75 per cent in October, 67 per cent in November, and 41 per cent in April.

Another, on site amelioration after two years, showed increased survival after mulching with black polythene sheet or ban mara (a common weed), but relatively little effect on growth. Adding six *mana* (3.5 l) of farmyard manure mixed with compost slightly improved survival, as compared with the control. In the control the young plants suffered from tip damage, which was not recorded in the treated plots. Even under the best treatment growth was very slow, 29 cm after two years. The experiments were replicated, but no data on significance levels have been published.

Among the best results in early growth in trials are those obtained by Napier and Parajuli (1987), at Hetauda (470 m) and Chalnakel (1370 m) with mean heights after 18 months of 1.5 and 1.6 m respectively. These were on soil which

had been weeded and thoroughly cultivated and to which 400 kg ha⁻¹ of Complexol (20:20:0) fertilizer had been added. Thus they represent somewhere near the optimum growth to be expected from these sites. Other reasonably good results were obtained at Pokhara (900 m) with mean heights of 1.3 m at 17 months and 2.3 m at 34 months (H.B. Thapa and Budathoki, 1987); Karmiya, in the Terai, 1.9 m at two years (M.B. Karki, 1988); and Tistung, under pine shelter, 1.1 m at 2.5 years.

At the Pakhribas Agricultural Centre, Y.B. Malla (1988) made records of trees planted by farmers at altitudes between 1300 and 1900 m. Height growth was as follows: one year 1.5 m; two years 2.4 m; three years 3.3 m; four years 3.1 m; five years 4.1 m; six years 4.4 m; seven years 4.5 m; and eight years 5.4 m. Diameters at breast height ranged from 5.1 cm aged three years to 8.7 cm aged eight years. These results are better than any achieved in trials, and perhaps represent the effects of care given to small numbers of valued trees by farmers.

Elsewhere, however, growth has been very slow at least in early life, with 30 cm height at age two years, and perhaps 50 cm at age three years being typical figures. Although in trials there is a tendency for height growth to decline with increasing altitude, there are many exceptions to this trend. *Ficus auriculata* appears to be a species which will only grow well if it is thoroughly tended, and should not be planted where this is not possible.

Uses

The main use of *F. auriculata* is as fodder. Although semi-evergreen its main season of leaf-fall is in the spring dry period, between mid-December and mid-March; new leaves flush soon after. In Lamjung District farmers lop the trees twice in a year, first between mid-April and mid-June, and secondly between mid-September and mid-November (K.P. Gajurel *et al.*, 1987). In other places the leaves are used between December and March. Sometimes the trees are completely defoliated.

The leaves contain about 13 per cent crude protein, varying from 11 per cent in the dry season between October and February, and 13 per cent in the monsoon, to almost 15 per cent in March–April, after the new flush. Dry matter contents for the same periods were 40, 27, and 37 per cent respectively (Subha and Tamang, 1990). The tannin content is fairly low, with peaks in December and March. Feeding the leaves sometimes causes dysphagia, and in trials at Pakhribas addition of them to basic rations decreased milk yields of buffaloes, in contrast to other species which increased milk yields. Yields of fodder (fresh weight of leaves and twigs) were recorded by Heuch (1986) as follows (Table 42).

Table 42—Yields of fodder from *Ficus auriculata*

Age (yr)	Total fodder (kg)	Leaves (kg)	Twigs (kg)
5	25	—	—
6	49	—	—
7	109	—	—
8	142	—	—
8	153	—	—
10	154	70	84
11	212	200	12
12	218	204	14
13	208	189	19
14	264	168	96
15	365	212	153

The fruit is edible, and is used for making a sort of jam. In the Pokhara area two varieties are distinguished; seto nimmaro growing between 1200 and 1600 m, and rato nimmaro from 1600 to 2000 m.

Importance in Nepal

As with other fodder species, its importance varies between different localities, but in a number of districts it is one of the species most preferred by farmers. In Salle village, Dhankuta District, it was by far the most preferred fodder species; in 1989, 85 per cent of farmers already had *F. auriculata* trees on their land, and 75 per cent took seedlings for planting (B. Thapa *et al.*, 1990). It also has been recorded as the preferred fodder tree in Lumle and other places. Because it needs good care and tending it is more suitable for planting by individual farmers than in larger scale plantations.

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhane and Joshi (1980); Mader and Stewart (1983); Panday (1976a; 1979; 1982); R.V. Singh (1982); Troup (1921).

***Ficus benghalensis* L.**

Nepali: bari, bohar.

Banyan.

Ficus benghalensis can be found throughout Nepal up to about 1800 m usually planted for shade on chautaras. It is sacred to Hindus. The trees send down numerous aerial roots from the branches, which take root when they reach the ground to form new trunks; in this manner old trees may cover very large areas. It is a strong light-demander. Seedlings are fairly resistant to frost; they often dieback, but later recover. The tree at all stages is killed by fire. It is evergreen except for a short period. The figs ripen between March and April; about 800 weigh 1 kg, and there are about 2.5 million seeds kg⁻¹. Seedlings are raised in the usual way. The tree can also be raised from hardwood cuttings 30 cm long by 1 cm in diameter, or from large branch cuttings about 2 m long. The latter method is preferred in India. The leaves contain 8–11.5 per cent crude protein, which increases as the leaves mature. However it is not an important fodder tree in Nepal. The fruit can be eaten (D. Bajracharya *et al.*, 1985). The wood is occasionally used in India, although Hindus generally object to felling the tree, and a coarse fibre used for ropes is made from the bark and aerial roots. However the main values are for shade and ornament, and its religious importance.

References: M.W. Campbell (1983a); Gamble (1922); Napier and Robbins (1989); Panday (1982); R.V. Singh (1982); Streets (1962); Troup (1921); Webb *et al.* (1984).

Ficus clavata see *F. subincisa*.

Ficus cunia see *F. semicordata*.

***Ficus glaberrima* Blume**

Nepali: pakhure.

It occurs mainly between 600 and 1500 m, but is not found growing naturally in eastern Nepal. It is however an important fodder tree in other regions, especially in the Pokhara area. The month in which seeds ripen appears to be very variable; records show that seeds have been collected in almost every month in the year. Van Ginkel (1984) writes that the figs are usually collected in the monsoon, though at lower altitudes collection begins in February; but collection in November has also been recorded. The figs are of one sort, and all contain fertile seeds. There are about 2.5–3.5 million seeds kg⁻¹.

Below 700 and 1500 m the seed should be sown in early or mid-February, to produce plantable seedlings by the monsoon. Above 700 m almost a year in the nursery will be needed, and the seed should be sown in August. Reports from community forestry nurseries state that germination took between 25 days and nine weeks, but use of better techniques, as described under *F. auriculata*, should improve this, and also the germination rates. The best result reported from nurseries in 1982 was the equivalent of 13,000 seedlings from 1 kg of seed; the median value was only 4000 which indicates very poor germination. *Ficus glaberrima* can also be propagated by air layering. Two-year-old branches are girdled in February and March, and the girdled area covered with a rich mixture of soil and compost, which must be kept moist. After roots have been formed, the branch is cut off and planted in the field at the beginning of the monsoon. Farmers also propagate it by using large cuttings planted directly in the field; they say such cuttings should not be taken from trees previously propagated vegetatively (Robinson and KC, 1990).

Little information is available on growth rates. In some cases early growth would appear to be slow. Trees planted at Naldung (1500 m) averaged 23 cm after 16 months, on an exposed site. The mean height of trees planted by farmers at Lumle was about 50 cm after one year. At Karmiya, in the Terai, trees were 1.4 m high at two years. At Adabhar (120 m) trees five years old were more than 2 m high by 7–8 cm diameter at 30 cm from the ground (S.M. Amatya, 1992). At Nijgad in the Terai good growth was obtained by planting in very large (75 cm x 75 cm x 75 cm) pits.

In Lamjung District the trees are lopped for fodder twice a year, from mid-October to mid-November, and mid-March to mid-April (K.P. Gajurel *et al.*, 1987). No information is available on crude protein content of the leaves. The tannin content is rather high, especially in November, and February to March. S.M. Amatya (1992) found that at Adabhar (120 m) trees five years old, averaging 8.0 cm in diameter, when lopped in November yielded an average of 10.6 kg per tree green matter, of which 9.0 kg was leaves; trees 6.9 cm in diameter, lopped in March, yielded 13.8 kg per tree of dry matter and 9.9 kg leaves. He gives regression equations relating yields to diameter. For older trees, in Kaski District of the Western Development Region, Vaidya and Gautam (1989) reported yields in fresh weight of fodder averaging 424 kg (277–527 kg) from trees averaging 14.1 m high and 46 cm in diameter at breast height (range 12.1–19.0 m and 38–54 cm respectively). This agrees with the figure of 375 kg per tree reported by K.P. Gajurel *et al.* (1987). As with most fodder trees the importance of *F. glaberrima* varies a good deal between different districts. As mentioned, it is absent from eastern Nepal, and it is not included in the fodder trees in Dhading and Bara Districts described by Upad-

hyay (1991) or Lalitpur District (Upton, 1990). Against this it is fairly important in Lamjung District (K.P. Gajurel *et al.*, 1987) and in Rahi panchayat in Pokhara Forest Division it is the commonest tree used for fodder; about one in five of all fodder trees in this area is a *F. glaberrima* (Hawkins and Malla, 1983).

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhaney and Joshi (1980); Napier and Robbins (1989); Panday (1982); Mader and Stewart (1983).

Ficus hispida L.f.

Nepali: khasreto, thotne, tote.

Occurs in all regions of Nepal, up to 1100 m. It is a small to moderate-sized tree, often found in ravines and shady places, and on farms. It is frost-tender. It coppices well. It has not been raised in nurseries to any great extent. The seed, according to Troup (1921), ripens at most seasons. Nepal records are from October to December, May and July, so this seems to apply here also. There are about 8 million seeds kg⁻¹. Germination takes 2–3 weeks. The tree can also be raised from cuttings. It is locally fairly important as a fodder tree; in two of the three village development committee areas near Pokhara studied by Hawkins and Malla (1983) it formed seven and 7.8 per cent respectively of the trees used for fodder. In the households in Lamjung District studied by K.P. Gajurel *et al.* (1987) it produced about three per cent of the leaf fodder supply. It is also used on a moderate scale in Dhading District, and in Ratanpuri, Bara District (Upadhyay, 1991). However it is not included in the list of fodder trees used in Lalitpur (Upton, 1990). The leaves contain 12–16 per cent crude protein. In Lamjung there are two harvests a year, in mid-September to mid-October, and mid-March to mid-April; farmers there estimate the yield to be about 50 kg per tree each year. In Dhading leaf fall occurs during the spring dry period, between mid-February and mid-April, and the new flush between mid-April and mid-June. There the main periods of lopping are mid-April to mid-June (pre-monsoon), mid-October to mid-December (post-monsoon) and mid-June to mid-October (monsoon). In Bara they are slightly different, being monsoon, pre-monsoon, winter (mid-December to mid-February) and post-monsoon, in that order of importance. There is little information available on growth rates, though some farmers consider it a relatively fast-growing species.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Panday (1982); R.V. Singh (1982); Troup (1921).

Ficus infectoria see *Ficus lacor*.

***Ficus lacor* Buch.-Ham.**

(Syn. *F. virens* Ait., *F. infectoria* auct. non Willd.)

Nepali: kabro, kavro.

Found in all regions of Nepal, up to about 1600 m. It is a small deciduous or nearly evergreen tree, which grows on a variety of soils; however good growth is only obtained on moderately deep soils with an adequate moisture supply. It has some tolerance to frost, but the seedlings are very susceptible to damage by browsing and fire. There is only one type of fig, containing both seed and gall-flowers. Seed is generally collected between March and May; its germination rate is usually rather low. Laboratory figures are 15 per cent. There are between 2.5 and 3.5 million seeds kg⁻¹. In nurseries in Nepal the equivalent of between 3500 and 67,500 plants have been raised from 1 kg of seed. Damping-off, and ants eating the seed, are problems in nurseries. Kessler (1981) failed to find viable seed of this species in the Pakhribas area. Growth in the nursery from seed is rather slow, and seed needs to be sown in August to produce plantable seedlings by the next monsoon.

Ficus lacor is commonly propagated by cuttings. Hardwood cuttings, 1–2.5 cm thick, and 25–30 cm long, taken in February and rooted in polypots can be planted after 4–5 months in the nursery but are rather soft at this stage. Large cuttings (2 m) are the traditional method of propagation used by farmers; air layering is also possible. Stumps have been used successfully in India. It has also been successfully propagated *in vitro*, from shoot tips of a tree 2 m high; 20,000 seedlings were raised by this method. For details see N. Amatya and Rajbhandary (1991).

Early growth rates are rather slow. At the age of 18 months trees planted on cultivated and fertilized land averaged 1.4 m in height at Hetauda (470 m) and 1.0 m at Chalnakhel (1370 m). At approximately the same age they averaged 21 cm at Naldung (1600 m) and 34 cm at Thulo Sirubari (1400 m). At Nisikot trees 27 months old averaged 40 cm in height. On all these sites survival was good. Trials planted at Murtidhunga (1500 m) and at Salle (2000 m) failed. These results from seedlings suggest that large cuttings as used by farmers, in which the height at planting is 1.5 m or more, would be preferable.

It is a valuable fodder tree. According to Subba and Tamang (1990) the mean dry matter content of the leaves is 32 per cent, ranging from 28 per cent during the monsoon to 36 per cent in the dry season; they found the mean crude protein content of the leaves to be 14.3 per cent, being slightly higher in spring (March–April) than at other times of the year. Other sources give a crude

protein of between 8.5 and 15.7 per cent. In Dhading District some farmers say that feeding the leaves during the pre-monsoon period may cause health hazards, although this is one of the main periods of use. It was recorded as forming 8.5 per cent, by number, of the trees used for fodder in Rahi, Pokhara (Hawkins and Malla, 1983), and in Lamjung District it was estimated to yield about 11 per cent of the total leaf fodder supply (K.P. Gajurel *et al.*, 1987). It is also used, but on a rather minor scale, in Dhading District, and in both the Terai and foothills of Bara District studied by Upadhyay (1991). In Lalitpur District it is mainly used from south-facing slopes between 1000 and 1250 m, and then only on a small scale (Upton, 1990). In Bara District (Terai and foothills) the leaves flush between mid-February and mid-March, but in Dhading at higher altitudes rather later, about April. The main period for lopping is usually the pre-monsoon between mid-April and mid-June but in Bara District lopping during the monsoon and post-monsoon periods is also important. Near Dhan-kuta, also, lopping is important between mid-November and mid-January. In some localities the trees are lopped twice during the year. Panday (1982) reports an annual yield of fresh leaves of 100–150 kg per tree, and K.P. Gajurel *et al.* (1987) 175 kg.

In addition to fodder the trees produce quite a large yield of fuelwood, and sometimes are heavily lopped for this purpose. According to Chaturvedi *et al.* (1986), the calorific value of the wood is 28,500 kJ kg⁻¹ and density 460 kg m⁻³. The wood burns slowly but produces rather large amounts of irritant smoke. The young leaf buds are used for making *achar*, a sort of chutney.

References: M.W. Campbell (1983a); Gamble (1982); Kessler (1981); Lamichhane and Joshi (1980); Mader and Stewart (1983); R.V. Singh (1982).

Ficus nemoralis see *Ficus neriifolia* var. *nemoralis*

***Ficus neriifolia* Sm. var. *nemoralis* (Wall. ex. Miq.) Corner**

(Syn. *F. nemoralis* Wall. ex Miq.)

Nepali: dudhilo.

Tamang: mago.

Silvicultural characteristics

This fig occurs at rather higher altitudes than most others, growing mainly between 900 and 2200 m. It is a small deciduous tree and from its distribution would probably be more frost-tolerant than other figs. Near Lumle seedlings were damaged by unusually early snow, but shot again from the base. It will tolerate soils of high pH, for instance it grows in gullies on the old river terraces

in Pokhara, and at Rautahari, in the Terai, was recorded on a soil with pH 6.8 in the topsoil, and 8–8.2 in the subsoil. As with most figs the seed is disseminated by birds, and groups of 20 or more seedlings have been found under thinned out pine plantations at Tistung. It is one of the species found in degraded *Schima–Castanopsis* forest after protection.

Artificial regeneration

There are two types of figs, one with seed and one containing gall-flowers, occurring on different trees. The seed ripens between early June and mid-August, when the receptacles turn blue-black. There are about 1.6 million seeds kg^{-1} . Laboratory germination was recorded at 41 per cent but in the field rates much lower than this have been recorded, with between 1000 and 14,000 plants raised from 1 kg of seed, the median being about 3500. Panday (1982) states that the seed needs a certain period of dormancy before it will germinate, but this is not shown up in the nursery records. At altitudes between 700 and 1500 m seed sown in July or August will produce plantable stock by the onset of the next monsoon. At higher altitudes sowing should be in March or April, giving the seedlings a total of about 15 months in the nursery.

Harrison (1989a) did some experiments on different proportions of soil and compost in the potting mixture. Seed was sown in August and the seedlings pricked out in October. When measured in June height and root-collar diameter steadily increased with the proportion of compost, from 31 cm and 0.49 mm with no compost, to 39 cm and 0.57 mm with 40 per cent compost. However the seedlings grown without compost would have been of plantable size, so in this particular case compost was unnecessary.

Stumps from 15-month-old seedlings were planted successfully at Nagarkot (1850 m). They were raised by pricking out plants from germination trays into beds at 20 cm x 15 cm, and cutting them to 3 cm stem and 12 cm root. These stumps put out an average of five new shoots each after planting; multiple stems are an advantage in a fodder tree. Satisfactory results were also obtained from the use of large bare-root seedlings, raised in beds in the same way. They were 78 cm high two months before planting, and transported with their roots packed in soil. Heavy grazing damage prevented more detailed assessment (Paudel, 1990). Propagation by hardwood cuttings is possible if proper techniques are used, and at Chalnakhel 47 per cent of cuttings taken in March rooted successfully. Farmers traditionally propagate *F. neriifolia* by the use of large cuttings 150–200 cm long. According to Panday (1982) propagation by air layering is also possible.

Various trials have been made of different planting methods. At Pakhribas in 1980 trials were made of planting at the ends of February, April, June, July,

August and September. There were no significant differences in survival and height, or increment from the seedlings planted in the different months, but the lowest survival rate, 76 per cent, was obtained from February planting. In the same year trials were also made of bare-root planting in July, and there was no significant difference between the survival and increment rates of bare-root plants and those raised in polypots. All the trials were at about 1800 m. The year 1980/81 was considered to be particularly favourable climatically (P.R. Pradhan, 1982b). Until similar results are obtained elsewhere standard practices of planting in the monsoon should be continued; however, the results quoted previously confirm that in some circumstances properly prepared bare-root plants can be successful. A number of trials of the use of fertilizers and compost have been made. In general there has been a positive response to fertilizer; for instance at Thulo Sirubari, 25 or 50 g of Complexol (20:20:0) per tree increased height growth at the age of 3.5 years from 1.0 to 1.6 and 1.7 m, and survival from 75 to 84 and 85 per cent, respectively. However compost had even better results on survival (91 per cent) and similar results on height growth (R. Shakya, 1991). This response to fertilizer is not universal however, and there are instances where use of fertilizer has depressed growth. Planting under the shelter of other trees, particularly pines, is beneficial; for instance at Tistung (1900 m) the following results were obtained after 18 months (Table 43).

Table 43—Growth of *Ficus neriifolia* under pines

	Open		Shade	
	No Compost	Compost	No Compost	Compost
Survivors (%)	87	100	100	100
Mean height (cm)	26.1	29.6	33.7	36.5

Note: The compost was applied at the rate of half a *pathi* (2.2 l) per tree.

Rate of growth

Ficus neriifolia grows rather more rapidly than most figs, but not as fast as *F. semicordata*. At Chalnakhel (1370 m) on a weeded, cultivated site with fertilizer added it was 1.9 m high at 18 months. Other reasonably good growth rates were 1.6 m at 28 months at Kadambas (1500 m) and 1.5 m at 30 months at Tistung (1900 m) (under shelter of pine). On poorer sites or with less care 60 cm at two years and 70 cm at three years would be common growth rates.

Uses

Its main use is for fodder. The leaves fall between mid-February and mid-April, and the new flush appears between April and mid-June. They have about 13 per cent crude protein, ranging from 11.8 per cent in the October–February dry period through 12.8 per cent in the monsoon to 13.9 per cent in spring (March–April) (Subba and Tamang, 1990). The tannin content is moderate, peaking in November, January and February (Wood *et al.*, 1992). In India it is said that saponin in the leaves may cause haematuria (R.V. Singh, 1982), and farmers in Dhading District say that eating them may cause a health hazard, especially in May and June.

The trees are lopped for fodder from January to February and again from May to June after the flush of new leaves has appeared. The estimated annual dry weight fodder yields are 18, 34 and 74 kg, from trees 20, 30 and 40 cm in diameter respectively (T.J. Wormald *et al.*, 1983). Its popularity and importance vary between different districts. In Dolakha District, it is the second commonest but most popular fodder species, and the one most in demand for planting (Robinson and Neupane, 1988). In Salle village, Dhankuta District, every farmer had some trees, and the average number was 35 per farm, but the demand for trees for planting was less, only 12 per cent of farmers taking seedlings; in their planting they had 90 per cent survival. In Lalitpur District it is mainly important above 1500 m, and between 1250 and 1500 m on south-facing slopes, with April the most important lopping period (Upton, 1990). In Dhading it is used, but is not one of the most important species; trees in the forest there are more important than trees from farmers' own land. It is also used, but on a rather small scale, in Ratanpuri, Bara District (Upadhyay, 1991).

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Panday (1982); R.V. Singh (1982).

Ficus religiosa L.

Nepali: pipal.

Pipal or Bo tree.

Ficus religiosa is thought to be indigenous in the sub-Himalayan hills, but as it is a tree sacred to both Buddhists and Hindus it has been very widely planted in south and southeast Asia. In Nepal it is one of the commonest species planted on *chautara*, often together with *F. benghalensis* (banyan or bar pipal). The seed ripens in April and May, and there are about two million seeds, and 4500 dry receptacles, per kilogram. The seed is sensitive to both excessive moisture

and to drying out, and percentage germination is usually very low. Seed sown in June will produce plantable seedlings by the onset of the next monsoon. It can also be propagated by hardwood cuttings taken in March to April, or by large branch cuttings 2 m long by 5 cm in diameter, or from stumps. In Nepal the young flush of leaves is used for fodder, but only for sheep and goats. Older leaves are fed to elephants (Storrs and Storrs, 1984) but these are scarcely important domestic animals in Nepal. The crude protein content of the leaves is about 14 per cent. Leaves, bark, fruit and seeds have medicinal uses. According to Chaturvedi *et al.* (1986) the wood has a calorific value of about 26,400 kJ kg⁻¹, and burns slowly, producing a moderate amount of smoke.

References: M.W. Campbell (1983a); Galil (1984); Galil and Meiri (1981); Gamble (1922); Lamichhaney and Joshi (1980); Panday (1982); R.V. Singh (1982); Troup (1921).

Ficus roxburghii see *F. auriculata*.

***Ficus semicordata* Buch.-Ham. ex Sm.**

(Syn. *F. cunia* Buch.-Ham. ex Roxb.)

Nepali: khanyu.

Nepalese people distinguish two varieties of khanyu: khasro khanyu and rai khanyu. These have been studied by S.M. Amatya (1991), who has described two botanical varieties, *F. semicordata* var. *semicordata* and *F. semicordata* var. *montana* respectively. Unfortunately var. *montana* has not yet been validly published (no Latin diagnosis); it is hoped that this will be remedied soon. The principal distinctions between the two varieties are as follows.

Margin of leaves, at least in part, serrate, with variable sized teeth; upper surface rough; midrib and veins with short to medium hairs; lower surface of leaf with long shaggy hairs; six basal and 9–14 pairs of lateral veins; veins branching just within margin; midrib of fresh leaves creamy-white; figs 1.5–2.5 cm in diameter var. *semicordata* (Nepali: khasro khanyu)

Margin of leaves with minute serrulate teeth or none; upper surface smooth; midrib and veins with appressed hairs; seven basal and 10–21 pairs of lateral veins; veins forming marginal loops; midrib of fresh leaves pink; figs 1.0–1.5 cm in diameter var. *montana* (Nepali: rai khanyu)

Some writers have called khasro khanyu *F. cunia* and rai khanyu *F. semicordata*, but this usage is incorrect. The two varieties differ in distribution, growth rates, and value as fodder; these will be discussed below.

Silvicultural characteristics

Ficus semicordata occurs from the Terai to 2000 m, with khasro khanyu throughout this range, and rai khanyu over 1400 m. Both are small to medium trees which are deciduous for a short time in the year. They are light-demanders and are said to have some tolerance to frost, but are easily killed by fire. *Ficus semicordata* is one of the first species to regenerate naturally on eroded sites (Olsson, 1983). It coppices well.

There are two types of figs borne on different trees, the first containing male and gall flowers, the second female and pseudo-hermaphrodite (male with a non-functional, non-gall-forming ovary). In the west of Nepal farmers call the gall figs *wakche khanyu* (literally figs which cause vomiting) or *akhaje khanyu* (inedible) and the seed figs *khaje khanyu* (edible). The figs on the lower part of the leafless branches may develop in leaf litter and humus, and be buried in the surface of the soil, where the seeds germinate. Otherwise birds and other animals distribute the seeds.

Artificial regeneration

The seed is collected between July and October, care being taken to collect only seed-containing figs. There are 1.5–3 million seeds kg⁻¹. The percentage germination in laboratory conditions is about 14 per cent, but frequently many seedlings die in the nursery, and the number of plants raised per kilogram of seed has ranged from 1400 to 45,000. The time taken for the seed to germinate is also very variable, from five days to nearly six months. The young seedlings have a rosette habit and great care is needed when they are pricked out to ensure that the horizontal leaves do not touch the soil surface, while at the same time the roots are not exposed. Below 700 m seed sown in late February will produce plantable stock by the monsoon; at higher altitudes seed should be sown in early August for seedlings to be planted in the next monsoon. Propagation by hardwood cuttings is possible, though the rooting percentage tends to be rather low. Of hardwood cuttings taken in March at Chalnakhel the rooting percentage of khasro khanyu was 22 per cent, of rai khanyu 12 per cent. Air-layering is also said to be possible.

L. Joshi and Sherpa (1992) report results from plantation trials at Pakhribas (1700 m). Addition of compost/farm yard manure increased height growth, as did mulching with black polythene sheet. The most dramatic increase in height growth, more than twice that of the other treatments, was obtained by mulching with ban mara. However this reduced survival from over 94 per cent to 61 per cent, after two years. No explanation is suggested. Another experiment, on planting dates, gave 100 per cent survival for trees planted in April, May, June, August and September, 83 per cent for October and 58 per cent for November.

Planting in very large pits (1 m x 1 m x 1 m) has given good results at Nijgad, in the Terai. On exposed sites at higher altitudes planting under the shelter of pines is beneficial.

Growth rates

Ficus semicordata is the fastest-growing fig so far found, and rai khanyu is faster than khasro khanyu. At Chalnakhel (1370 m) after 18 months rai khanyu averaged 3.4 m in height, and khasro khanyu 1.8 m. This was on cultivated and weeded ground, with added fertilizer, and is probably near the optimum growth for this site. At Hetauda (470 m) khasro khanyu averaged 2.9 m in height at this age. Survival was over 90 per cent at both sites (Napier and Parajuli, 1987). At Kadambas (1450 m) aged 3.3 years rai khanyu averaged 1.02 m in height and khasro khanyu 0.76 m, survival of both being good. Only at Chirtungdhara in Palpa District (800 m) was the performance of khasro khanyu better than that of rai khanyu; height growth of both varieties was similar (168 and 167 cm respectively), but survival of khasro khanyu was 90 per cent, against 77 per cent for rai (Neil, 1990d). Some rai khanyu trees five years old at Adabhar reached 15 cm diameter at 30 cm from the ground (S.M. Amatya, 1992). Y.B. Malla (1988) measured *F. semicordata* trees (variety not stated) planted by farmers in the Pakhribas area, and obtained the following results (Table 44). He points out that some farmers not only protected the trees but also weeded, mulched and manured them. These growth figures thus represent what can be obtained from well-tended trees.

Table 44—Growth of *Ficus semicordata*

Age (yr)	Height (m)	dbh (cm)
1	1.5	—
2	1.9	—
3	2.8	3.4
4	3.4	5.7
5	3.1	5.9
6	—	—
7	4.3	7.4
8	6.0	7.3

Uses

It is a useful fodder tree. The variations in leaf composition during the year for the two varieties is shown in Table 45, from Subba and Tamang (1990). The tannin content of the leaves is rather high, with a peak in December, and a subsidiary peak in March (Wood *et al.*, 1992). Farmers say that feeding the leaves during the pre-monsoon period may cause health problems. 9.4 kg of fodder eaten per day by buffaloes increased milk yield by 0.36 kg day⁻¹ (N.P. Shrestha and Pakhrin, 1988).

Table 45—Leaf composition of *Ficus semicordata* throughout one year

	rai khanyu		khasro khanyu	
	dry matter (%)	crude protein (%)	dry matter (%)	crude protein (%)
Mar–Apr	40.3	11.6	39.2	10.5
May–Sep	35.5	10.2	35.4	10.2
Oct–Feb	41.5	10.6	42.5	9.4
Yearly average	38.7	10.6	37.5	9.9

Ficus semicordata trees are often lopped twice in a year; occasionally three times (Tengnas, 1981). Lopping can take place at almost any time in the year, but is rather more common during the pre-monsoon (mid-April to mid-June) in most places. The following yields (Table 46) were recorded from rai khanyu trees five years old, at Adabhar, by S.M. Amatya (1992). They compare with yields of 8, 13 and 18 kg of dried leaves per annum produced from trees of 20, 30, and 40 cm in diameter respectively, estimated by T.J. Wormald *et al.* (1983); and 50 kg fresh weight per tree estimated by K.P. Gajurel *et al.* (1987).

Table 46—Yields of fodder obtained from five-year-old *Ficus semicordata* trees growing at Adabhar

Month lopped	Mean diameter (cm)	Mean green matter branches and leaves (kg)	Mean green matter leaves only (kg)
November	15.0	27.5 +/- 5.2	18.7
March	13.4	33.8 +/- 9.0	27.8

The importance and popularity of *F. semicordata* varies with the district. At Pakhribas and Lumle it was the second most popular tree for planting by farmers, but was among the least popular in Lamjung District (K.P. Gajurel *et al.*, 1987) and was not very popular for planting in Dolakha District. Rai khanyu is preferred to khasro khanyu. Rai khanyu was being lopped in Lalitpur District, on north-facing slopes below 1250 m altitude between November and April, by an average of 70 per cent of farmers questioned. It was less important at other altitudes, and on south-facing slopes, where khasro khanyu took its place, also with 70 per cent of the farmers questioned using it in the same period (Upton, 1990). In Dhading District it was the third most used species from farmland, but little used from forest and fallow land. In Bara District it was not used in Bariyapur, in the Terai, but was the most used species from farmland, at Ratanpuri at 300 m, at the base of the Siwaliks. In Dhading District farmers prefer it mainly because of its fast rate of growth, high production of foliage, and as a multipurpose tree. Its nutritional value is not ranked very high (Upadhyay, 1991). It was estimated to produce about 1.5 per cent of the total tree fodder used in the area of Lamjung District studied by K.P. Gajurel *et al.* (1987). The figs are edible, except for those containing gall flowers. In Kaski District the gall figs are said to cause swelling of the eyes of livestock which eat them (S.M. Amatya, 1991).

References: S.M. Amatya (1991); M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhane and Joshi (1980); Napier and Robbins (1989); Panday (1982); R.V. Singh (1982); Troup (1921).

***Ficus subincisa* Buch.-Ham. ex Sm.**

(Syn. *F. clavata* Wall. ex Miq.)

Nepali: berulo, gedilo, ankha pakuwa.

A shrub or small tree growing up to about 1800 m. There are two types of fig, seed figs and gall figs, on different trees; the seed figs are smaller than the gall figs. The seed is collected in July and August. There are about seven million seed kg⁻¹. According to Panday (1982) it needs a certain period of dormancy. At altitudes below 700 m it should be sown in early to mid-February; over 700 m in early August. The tree can also be propagated by cuttings. It is a fairly popular fodder though it is not used on a very large scale, and has not been raised very much in community forestry nurseries. The leaves have a high crude protein content (18 per cent); they are preferred for feeding mainly before the monsoon rains in May and June, but are also lopped between November and March. Farmers in Dhading District say feeding them in the pre-monsoon

season may cause health problems, and according to R.V. Singh (1982) feeding them to calves may cause skin disease. Vaidya and Gautam (1989) found that trees of mean height 5.6 m and mean diameter at breast height of 26 cm produced a yield of 56 kg fodder, fresh weight. The range was from 35–84 kg.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Napier and Robbins (1989); Panday (1982); R.V. Singh (1982); Upadhyay (1991).

Fraxinus L.

Oleaceae

Fraxinus floribunda Wall.

Nepali: lankuri.

Ash.

Large tree with grey bark. Leaves opposite, pinnate, with 7–9 serrate leaflets. Flowers white, with petals 3–4 mm long, in large branched clusters up to 25 cm across. Fruit a nut, with a long narrow wing 2.5–4 cm long by 3–4 mm wide.

Natural occurrence

It grows between 1200 and 2000 m, often in *Schima-Castanopsis* forest, and also sometimes as an understorey to *Pinus roxburghii*, where it may be part of a seral stage in the succession to hardwood forest. It is nowhere very abundant in natural forest. It is commonly planted on *chautara*. Outside Nepal it extends from the Punjab in the west, and to Assam and southwest China in the east.

Silvicultural characteristics

A large deciduous tree. The seedlings need full light, but older trees will withstand shade to some extent; trees planted together with *Alnus nepalensis* above Pokhara, although outgrown by the *A. nepalensis* and to some extent suppressed by it, remained healthy. From its altitudinal distribution it must certainly have some tolerance to frost, though this may vary with the provenance; seedlings in the nursery need protection. Although its growth is best on deep moist soils it is said to be one of the species which survive best on difficult sites (Grob, 1982). In parts of the Indian Himalaya it is associated with limestone, but in Nepal it is frequently found on non-calcareous soils. It coppices well.

Natural regeneration

The winged seeds ripen in September–January and are dispersed by the wind. Naturally dispersed seeds remain dormant through the monsoon after which they have fallen, and germinate in the next year. It was one of the species colonizing neglected plantations at Pipal Chaur in the Kathmandu Valley, although when it was previously planted there it failed. It also colonizes degraded *Schima-Castanopsis* forest, after protection.

Artificial regeneration

If it is to be sown immediately the winged fruit should be collected when it is still green; if it is left until it has turned brown the seed enters a dormant stage and will not germinate until the spring after it has passed through a complete monsoon season. Seed which is to be stored, however, should be collected when it is brown, as it then has a viability of three years, whereas seed collected when green loses its viability quickly.

There are about 60,000 winged seeds kg^{-1} . Two nurseries reported the equivalent of 7000 and 3600 plants raised from 1 kg of seed. At lower altitudes germination of green seed is rapid, beginning in 2–4 weeks and being complete within two weeks. At higher altitudes seed sown in September may not germinate until the following March.

Green seed should be kept moist and sown as soon as possible after collection. It may be sown directly into polypots, with two or three seeds per polypot sown vertically with their wings protruding from the soil. Alternatively it can be sown in beds or trays, and the seedlings pricked out into polypots a few days after they have germinated, before the first true leaves appear. The polypots should contain a mixture of three parts soil to one of sand.

Stand-out beds should not be shaded for more than a few days, otherwise growth is retarded and the seedlings may die (Grob, 1982). In many nurseries below 1500 m plants from seed sown in September–October will be ready for planting by the next monsoon, but at higher elevations a further year in the nursery may be needed. The seedlings should be spaced out when they are 20–30 cm tall, and regular root pruning is needed. Plantable seedlings are 25–30 cm tall with root-collar diameters of over 2 mm.

Rate of growth

The rate of growth is rather slow to begin with; in trials, trees 18 months old have been between 20 and 30 cm tall, and at 2.5 years about 70 cm. In Sankhuwasabha District of eastern Nepal, Sizeland (1986) reports a height of 5 m with 2 cm dbh from trees 4–5 years old planted on a deep fertile loam at 1100–1200 m, but only 1 m at the same age at 1900 m on a fertile loam with

Imperata present. In India naturally grown trees had a mean annual diameter increment of 4–6 mm (Gamble, 1922).

Uses

The wood is white with a light red tinge and weighs about 770 kg m⁻³. It is hard and tough and is used for ploughs and carrying poles. The tree is lopped for fodder but it is not one of the most important fodder trees. The main season during which it is used is between April and June, after the new leaves have appeared. According to D. Bajracharya *et al.* (1985) the crude protein content of the leaves is 7.5 per cent. A vigorous tree will produce 100 to 200 kg of fresh leaves in a year.

Importance in Nepal

It formed about three per cent of the stock of fodder trees, by number, in the area of Dolakha District studied by Robinson and Neupane (1988), but was not a popular tree among farmers, and was not in demand for planting. It was used on a very small scale in the area of Dhading District studied by Upadhyay (1991), but was not recorded in Lamjung by K.P. Gajurel *et al.* (1987) or in Lalitpur by Upton (1990), though farmers planted over 10,000 trees in the same district between 1985 and 1988 (Hausler, 1990). In general its use in plantations appears to be very local. Many community forestry nurseries do not raise it at all but in Pokhara and Ridi Divisions in 1981 it was the second commonest species planted. Its survival in the plantations of the Community Forestry Project in 1981 and 1982 was 76 per cent, the highest of any important broadleaved species planted. Its main disadvantage is its relatively slow growth.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Suri and Seth (1959); Troup (1921).

Fraxinus micrantha Lingelsheim differs in having patches of rusty-brown hairs at the apex of the shoots, and in the flowers having no petals. It is a higher elevation species found between 2100 and 3000 m.

Garuga Roxb.

Burseraceae

Garuga pinnata Roxb.

Nepali: dabdabe.

A large deciduous tree which occurs in Nepal up to about 1300 m. It is fairly common in *Shorea robusta* forest, especially near streams, and also grows in the Siwaliks in forests where *Anogeissus* is dominant. Outside Nepal its range extends from the Sutlej River in the west, eastwards to Indochina and Malaysia. It is a strong light-demander, and is sensitive to frost and drought, but very resistant to fire. It grows on a wide range of soils; in general soils which are suitable for *S. robusta* will also suit *Garuga*. It coppices well and produces root suckers. The fruits ripen during the monsoon. Some are eaten by birds which disperse the seeds; many however fall to the ground under the trees where the fleshy parts rot away. Most of the stones do not, however, germinate in the monsoon in which they fall, but in the following one; some may even lie dormant for two years. Seedlings are often found in abundance under seed bearers; young seedlings need abundant light, but are able to tolerate a moderate growth of grass and low weeds.

Seed is collected between June and September; there are between 4000 and 5000 kernels kg⁻¹. The pulp should be removed as soon as possible after the seed has been collected; dried seed can be stored for at least a year in sealed containers. Because of the natural dormancy of the seed, germination is uneven and prolonged: 240–340 days according to H.B. Joshi (1980). Hot water treatment is said to improve it. The seed should therefore be sown in beds, fairly thickly, and the seedlings pricked out into polypots as they appear. This should provide some plantable seedlings by the onset of the monsoon, if the seed is sown soon after it has been collected. *Garuga* can also be propagated from large cuttings 2 m long and up to 10 cm in diameter, and thus can be used for living fence posts. Sometimes farmers also propagate it by rooting cuttings in moist soil before planting, and by air layering (Robinson and KC, 1990). On good sites growth is rapid and plants have reached a maximum height of 3 m and a diameter of 4 cm in three years, from seed (Troup, 1921). Coppice regrowth is also rapid.

It is a medium quality fodder with a crude protein content of about ten per cent. The leaves fall between January and March, and the new flush appears between mid-March and mid-May. In a number of localities it is a very important fodder species, though often because of its abundance rather than its

superiority for fodder. In Naryanathan in Dhaulagiri Forest Division it is the commonest fodder tree owned by farmers, forming 30 per cent of the total fodder trees (Hawkins and Malla, 1983). There it is lopped from September to December. In Sunderbazar in Lamjung District it is also the most numerous fodder tree, forming 27 per cent by number of the total fodder trees enumerated. In this area it produces about 17 per cent of the total tree fodder. There it is lopped twice a year, between mid-April and mid-June, and mid-September and mid-October, producing an estimated green weight yield of 75 and 50 kg tree⁻¹, respectively, from each lopping. Though very widely used it is among the least popular trees for farmers to plant in this area (K.P. Gajurel *et al.*, 1987). In Dhading District it is of minor importance, but it is the most important species obtained from forest in Ratanpuri, at the foot of the Siwaliks in Bara District. There it is said that feeding the newly flushed leaves may cause health problems. Its main time of harvest there is between mid-October and mid-December, but it is also harvested in the pre-monsoon and monsoon periods (Upadhyay, 1991). It is of minor importance in Lalitpur District.

The fruit is edible. In India the wood is used for planking, packing cases, roofing and cheap grade furniture, and also for match splints. It is not durable. It weighs about 640 kg m⁻³ but according to Gamble (1922) is a bad fuel.

References: Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); H.B. Joshi (1980); Panday (1982); R.V. Singh (1982); Troup (1921).

Gleditsia L.

Caesalpiniaceae

Gleditsia triacanthos L.

Honey locust.

Considerable interest has been expressed in this species as a possible source of fuelwood and fodder for community forestry plantations, but unfortunately trials undertaken so far have not been successful. It has failed in all trials where it has been planted except at Thulo Chaur, Mustang District, at 2550 m, where at 17 months old there were 72 per cent survivors with a mean height of 17 cm (R.B. Joshi, 1985). It is a native of the United States, from the Appalachians and the Mississippi valley to Texas and Nebraska, and appears to be climatically unsuited to most of Nepal, except the arid Mustang area; even there results are not outstanding, but it is a very difficult area for trees. It is mainly valued for its pods, which are an excellent fodder, but it also produces a good timber and

fuel. It does not fix nitrogen. There are between 4000 and 9000 seeds kg⁻¹. The seed needs to be treated before it is sown, and the use of concentrated sulphuric acid is recommended. Failing this, hot water treatment could be tried. As it produces a very vigorous taproot, direct sowing into polypots is probably the best nursery technique.

References: Magini and Tulstrup (1955); National Academy of Sciences (1979); Streets (1962); Webb *et al.* (1984).

Gliricidia Kunth

Papilionaceae

Gliricidia sepium (Jacq.) Steud.

A small, fast-growing tree which is native to Mexico, Central America, and the northern parts of South America. It has been widely planted in tropical countries as a very fast-growing fuelwood and multipurpose species. However results in Nepal have on the whole been disappointing, despite trying a wide range of provenances on several sites.

The best results so far have been obtained from Adabhar, in the Bhabar Terai, with at 18 months 100 per cent survival, a mean height of 3.3 m, and a mean green weight above ground production of wood of 3.3 kg tree⁻¹, or 14.7 t ha⁻¹ at 1.5 m x 1.5 m spacing. Other species included in the same trial gave the following yields.

• <i>Acrocarpus fraxinifolius</i>	40.0 t ha ⁻¹
• <i>Indigofera teysmannii</i>	40.4 t ha ⁻¹
• <i>Cassia siamea</i>	15.9 t ha ⁻¹
• <i>Gliricidia sepium</i>	14.7 t ha ⁻¹
• <i>Dalbergia sissoo</i>	14.2 t ha ⁻¹

The only comparable growth figures seen are from Rautahat District, where the trees were 3.4 m high at 15 months old, but survival was only 65 per cent. At other sites growth was poorer. Particularly above 1000 m, heights at 15–18 months, of the best provenance tried, have ranged from 30 to 60 cm only. Details of other trials can be seen in Neil (1990g). No results so far justify planting on a large scale.

The poor results are, to a large extent, due to dieback during the cool, dry, winter months. *Gliricidia* is known to be frost-tender, but the dieback has also occurred in the absence of frost, for instance at Adabhar. Waterlogging, which the tree will not tolerate, has also caused poor survival on some sites. The best

results so far have been obtained from the provenances from Laguna Tecomapa, Matagalpa, Nicaragua; Piedra Larga, Esteli, Nicaragua; and Masaguara, Intibuca, Honduras.

There are about 8500 seeds kg^{-1} , with a viability of at least 12 months. Before being sown it should be treated with hot water; germination is good, up to 90 per cent. It should be sown directly into polypots. Two to three months in the nursery is adequate at lower altitudes. After the seedlings have reached a height of 5 cm they should be given full light. *Gliricidia* can also be easily propagated by cuttings 2 m long which should be planted directly in the field.

It has a hard, heavy wood, with a calorific value of 20,500 kJ kg^{-1} . The leaves are used as fodder for cattle, and contain about 20 per cent crude protein. They are, however, poisonous to other animals, including horses. The seeds are also poisonous, and were at one time used as a rat poison (hence the generic name, which means dormouse-killer). The leaves make a good compost. The tree is also used as a shade for tea and coffee, and as living fence posts. It fixes nitrogen.

References: M.W. Campbell (1983a); National Academy of Sciences (1980); Sherpa *et al.* (1992a); Streets (1962); Webb *et al.* (1984); Withington *et al.* (1987).

Gmelina L.

Verbenaceae

Gmelina arborea Roxb.

Nepali: gamari, khamari.

Large deciduous tree; bark pale light brown, fairly smooth. Leaves alternate, broadly ovate, with 3–5 basal nerves, 10–23 cm long. Flowers yellow, tinged with brown, about 4 cm long, in terminal dense clusters. Fruit a drupe, about 2.5 cm long, yellow when ripe.

Natural occurrence

In Nepal up to 1200 m. Frequently found in *Shorea robusta* forest, especially the wetter types. Outside Nepal it extends from Pakistan to Vietnam and southern China. It has been very widely planted in tropical countries as a fast-growing timber tree, and in particular as a source of wood for paper pulp.

Silvicultural characteristics

It is a deciduous tree, growing to more than 30 m high on favourable sites, but relatively short lived. It is a light-demander. Light frosts kill back the tops of the seedlings, but they frequently recover; repeated frosts however will cause the tree to assume a bushy form. *Gmelina* is very sensitive to soil conditions. It is capable of survival on poor dry sites, but its growth under these conditions is poor and trees on such sites are very branchy and stunted, and tend to stagnate after a few years. Its best growth is on freely drained, fertile soils, with no hardpan or other impediment to root development, in moist tropical regions. Pole crops will survive ground fires, but shed their bark. The tree coppices well.

Natural regeneration

Deer and cattle eat the fruit pulp and help to disperse the seeds, which germinate during the monsoon soon after the fruits ripen. Alternate heat and moisture are needed to stimulate germination, hence seed under dense shade will not germinate for lack of heat. The seed needs to become partially buried to germinate successfully, but if it lies among grass or weeds it usually will not germinate. Best results are found when the seed falls on cleared land, such as abandoned cultivation.

Artificial regeneration

The fruit in Nepal ripens between May and June, and should be collected from the ground when it is yellow. Brown or black fruits ferment rapidly and after only one or two days the germination percentage of the seed is greatly reduced. In any case the pulp should be removed from the kernels as soon as possible after collection; this can be done by rubbing the fruit against wire mesh and putting seed and pulp in water, when the seed will sink to the bottom. All the pulp must be removed from the kernel before it is spread out in the sun to dry. Properly depulped and dry seed will retain its viability for six months, possibly longer, and in cold storage (5°C) it is possible to store the seed for two years or more. There are on the average about 1600 kernels kg⁻¹, but each kernel may contain up to three seeds, rarely four.

Germination of *Gmelina* seed is often irregular. It should be covered with about 1 cm of topsoil, in beds fully exposed to the sun, and watered at least once a day; if this is done germination will begin in 7–14 days. The seedlings grow very rapidly in the nursery, and it may just be possible to raise plantable stock by the onset of the monsoon from seed collected in May and sown directly into polybags. Two months in the nursery is enough. However it is simpler to raise *Gmelina* as stump plants. The seed is sown at the beginning of the rainy season in rows in beds, and the seedlings kept in the nursery for a year, without shade

or irrigation. This should produce stumps about 2.5 cm in diameter, which are suitable for planting.

Gmelina has been successfully raised by sowing the seed directly into areas of forest that have been cleared and burnt. It is important, however, that burning should be thorough, and there should be no long delays between the burning and sowing the seed. In plantations *Gmelina* is very susceptible to grass and weed competition, and thorough, regular hoeing is essential if good growth is to be achieved. The use of taungya is very desirable when this is possible. *Gmelina* planted as stumps often produces multiple stems; these should be reduced to one per stump within a year after planting. Although some Indian sources advise against pure plantations, these have been raised on a very large scale in many parts of the world without any major problems.

Performance in plantations and rate of growth

It has only been planted on a small scale in Nepal. It was tried at Sagarnath but growth was moderate to poor (K.J. White, 1988b) and form poor. White attributes this to recurrent epidemic attacks of a shoot-boring insect, which kills the tree crown. However *Gmelina* does tend to be of poor form if grown on unsuitable sites; also provenance may be of importance. There is a plot at Chitripani where growth appears to be quite vigorous, but again form is poor. At Adabhar, in the Bhabar Terai, trees two years old averaged only 68 cm in height, although survival was 90 per cent. However this was in an area with dense grass competition, and weeding was confined to hoeing patches 30 cm in diameter round the plants. At Butwal (140 m) at the age of 18 months survival was 92 per cent, height 5.5 m, and dbh 6.5 cm, which is reasonably good. Outside Nepal, under very favourable conditions mean annual increments of 35–40 m³ ha⁻¹ have been recorded. In Nigeria, Quality Class 1 plantations had a mean annual increment of over 31 m³ ha⁻¹, but Quality Class 5 plantations only 4.5 m³ ha⁻¹; see yield table in Greaves (1981). This great difference in growth on good and poor sites is characteristic of the species.

Uses

The tree produces a highly valued timber, which is easy to work and durable and strong for its weight. It is creamy-white in colour, turning yellowish on exposure. It is used for a great variety of purposes including furniture and planking. It is also used for veneers and plywood, matches and as a source of paper pulp. It is rather light (420–640 kg m⁻³) but is otherwise a good fuel, with a calorific value of 20,100 kJ kg⁻¹. The charcoal burns well, without smoke, but leaves a lot of ash. The leaves are regarded as a good fodder, and the fruits are also eaten by cattle. They are also edible by humans.

Importance in Nepal

There are doubtless many sites in the lowlands of Nepal on which *Gmelina* could survive in plantations, but the really fertile sites needed for good growth are rarely likely to be available for forestry. Thus it is unlikely that *Gmelina* will ever be planted on a large scale.

References: A bibliography of *Gmelina* has been prepared (Greaves, 1980) and also a monograph on the species (Greaves, 1981), with a large number of references. Other references are M.W. Campbell (1983a); J. Evans (1982); Gamble (1922); Ghosh (1977); Indian Timbers (1974); Lamichhaney and Joshi (1980); Laurie (1974); Letourneux (1957); Magini and Tulstrup (1955); National Academy of Sciences (1980); R.V Singh (1982); Streets (1962); Troup (1921); Webb *et al.* (1984).

Grevillea R. Br.

Proteaceae

Grevillea robusta A. Cunn. ex R. Br.

Nepali: kangiyō.

Silky oak.

Trade name: *Grevillea*.

A straight stemmed tree with a dark grey bark, deeply fissured into long narrow scales. Leaves pinnate; leaflets usually with one or more large pointed teeth or lobes, especially on the edge nearest the twig. Flowers orange in dense one-sided clusters. Fruit dark brown, leathery, about 2 cm long. It is a native of Queensland and New South Wales, Australia, and was introduced into Nepal many years ago; it has been widely planted, mainly as an avenue tree. It is a light-demander. Seedlings in nurseries should be protected against frost. In the field young plants may be damaged by frost, but they will generally recover. It is sensitive to boron deficiency. In exposed situations the stems are liable to be broken by high winds. *Grevillea* does not coppice well, but can be pollarded. It produces a substance which is toxic to its own seedlings, but this does not prevent its being grown in close plantations, despite reports to the contrary.

In Nepal seed is collected between June and September. The capsules are dried in the sun and beaten to extract the seed. There are about 100,000 seeds kg⁻¹. After drying they can be stored in sealed containers for about a year, but the germination percentage drops from 60–70 to 35 during this period. In Nepal

nurseries much lower germination percentages have been recorded in practice. The seed is sown in beds or trays, and covered with a thin layer of soil. Germination begins 2–3 weeks after sowing and is complete about two weeks later. Seedbeds and trays should be shaded. The seedlings should be pricked out into polypots when they are at the four-leaf stage, and should be kept under shade for 2–3 weeks after pricking out; also at night in winter whenever there is danger of frost. Above 1000 m seed sown in August to September should provide plantable stock by the next monsoon; below 1000 m seed can be sown in February–March for seedlings to be planted in the monsoon of the same year.

It has been included in a few trials. At Butwal (140 m) at 30 months old it had 77 per cent survivors, mean height 3.8 m, dbh 4.3 cm; only moderate for this trial. At Palpa at two years it had stagnated. Over 1500 m early survival has been quite good, but growth rather poor (15–30 cm at 18 months).

Grevillea produces an attractive, durable timber used for furniture and many other purposes. The wood weighs about 570 kg m⁻³, and is a good fuelwood. However in Nepal its primary use is for ornament. It has been raised in a number of community forestry nurseries for distribution to farmers, and in some districts is a popular tree with them; in others not. The survival rate of plants issued to farmers in 1981–82 was 61 per cent, about average (J.G. Campbell and Bhattarai, 1983b).

References: M.W. Campbell (1983a); Ghosh (1977); Lamichhaney and Joshi (1980); Napier and Robbins (1989); National Academy of Sciences (1980); Streets (1962); Troup (1921); Webb *et al.* (1984).

Grewia L.

Tiliaceae

Trees or shrubs, with stellate hairs. Leaves alternate, usually toothed, with 3–5 veins at base. Sepals often coloured on inside; petals shorter than sepals; stamens many. Fruit a drupe, often deeply 2–4-lobed.

Key to the tree species

- (1) Flower clusters on stalks opposite to leaves; base of leaves three-veined, rounded; apex long-pointed; leaves rough above, hairy beneath; flowers cream or white with yellow stamens *G. optiva*
- (1) Flower clusters in leaf axils 2

(2) Base of leaf with five or more veins, rounded or heart-shaped; apex blunt to pointed; leaves with greyish white hairs on underside, or almost hairless; flowers yellow ***G. subinaequalis***

(2) Base of leaf with three veins **3**

(3) Leaf very narrow, about six times as long as broad, velvety beneath
..... ***G. helicterifolia* Wall. ex G. Don (*G. polygama* auct. non Roxb.)**

(3) Leaf less than three times as long as broad, almost hairless; flowers white ..
..... ***G. disperma* Rottb. (*G. laevigata* auct. non Vahl)**

***Grewia optiva* J.R. Drumm. ex Burret**

(Syn. *G. oppositifolia* Buch.-Ham. ex D. Don)

Nepali: bhimal, bhiyal, bhewul, bohadi, syal phusre, dhaman, ghaule.

(Some of these names are also used for other *Grewia* species.)

Natural occurrence

In Nepal from the Terai to 1700 m, exceptionally to 2200 m, in all regions, though it is more common in the west and centre. It extends west to Kashmir, but is not found east of Nepal.

Silvicultural characteristics

It is a moderate-sized, deciduous, light-demanding tree. It shows some tolerance to frost, though this may be expected to vary in a species with such a wide ecological range; frost often kills the tops of young seedlings, but they will shoot again from the base. The tree is susceptible to fire, and the seedlings to browsing. It coppices and pollards well. The seedlings and saplings may survive for some years on dry hill slopes, but growth is very slow on such sites; for good growth an adequate water supply is necessary.

Artificial regeneration

The fruit ripens in November to January, and turns from green to black. In some localities it may be necessary to buy or reserve trees for seed, but elsewhere it has been found possible to avoid doing this, by collecting the seed as early as possible, and if necessary persuading farmers to delay lopping slightly (J. Stewart, 1983a). However, germination of unripe green seeds differs from ripe black seeds (see below). There are about 6000 dried fruits, and 12,000–15,000 seeds kg⁻¹. After cleaning and thorough drying the seed can be stored in sealed polythene bags for at least a year without any serious loss of viability.

Germination of the seed is often considerably delayed and very irregular. This has been investigated by Burslem (1989b). He found that in green seed

germination was best when the flesh was removed, and the seed was kept under dry heat at 40°C for 24 hours. The next best treatment was not to remove the flesh, but with heat treatment; and the third best without removing the flesh and without the 40°C heat treatment. Treatment with water at 40°C resulted in nil germination, so hot-water treatments should not be used.

Black (ripe) seed behaved differently in some ways. Seed with the flesh removed germinated better than whole seed but the 24 hours dry heat at 40°C was harmful. Best results were from stratifying the seed, after removing the flesh, for 49 days at 5°C; stratifying the whole seed in a similar way gave rather lower but slightly quicker germination. In all treatments of both green and black seeds the time taken to complete germination was prolonged, usually over more than a hundred days. The first germination of green seeds was generally quicker, between 6–12 days, than that of the black seeds, where the best treatments took between 13 and 57 days before germination began. Burslem suggests that germination may be affected by a complex of factors, including inhibiting factors in the fleshy mesocarp and elsewhere, and maturation of seed and fruit. In practice the best time for sowing the seed is August, which means that stored seed must be used. According to Napier and Robbins (1989) August-sown seed begins to germinate within two weeks and most of the seed germinates quickly. This suggests that storage of the seed for several months may act in the same way as stratification. Germination of seed sown between October and March may not begin for several months and may then take a long time before it is complete. Percentage germination is usually low, between ten and 50.

In view of the rather low and irregular germination it is best to sow the seed in trays or beds and prick out the seedlings, rather than to sow directly into polypots. The seed should be sown on the surface of the soil at the rate of 500 g m⁻², and pressed down with a flat wooden board, and then lightly covered in soil or sand, and pressed down again. The seed needs ample moisture to germinate, and insufficient moisture causes much delayed and poor germination. The seedlings should be pricked out 2–3 weeks after germination has begun, when they have 2–3 true leaves. Fairly large (10 cm x 18 cm lay-flat) polypots should be used. If the soil is not too heavy and is moderately fertile no compost is necessary; otherwise 20 per cent compost should be included in the potting mixture. The seedlings should be shaded after having been pricked out, but the shade should be removed once they have begun to grow again, usually in 10–20 days, apart from shading during winter nights against frost. The pots should be spaced out in late April or early May. Regular root pruning is important. Overgrown plants may be pruned back two weeks before planting. At the time

of planting the seedlings should be 25–35 cm tall, with a well-lignified stem and a root-collar diameter of over 4 mm.

Successful rooting has been reported of hardwood cuttings taken in January or February. Stumps also have been successful. They are raised by sowing the seed in April, in drills 15 cm apart across the beds. In June the seedlings are thinned out to 15 cm apart in the drills. By the following monsoon, in July, 15 months after sowing, the seedlings should be 1.5–2 m tall. For making into stumps those with root-collar diameters of 5–20 mm should be used, with their shoots cut back to 5–7 cm, and their roots cut back to about 20 cm.

Performance in plantations and rates of growth

Growth rates are moderate. At Hetauda (470 m) on cultivated, weeded, and fertilized soil survival after 18 months was 100 per cent and mean height 1.7 m (Napier and Parajuli, 1987). At Pumdri Bhundi in Kaski District, near Pokhara, at the same age there were 74 per cent survivors with a mean height of 91 cm (Vaidya and Gautam, 1989). However, also at Pokhara, M.B. Karki (1988) reports a mean height after two years of only 36 cm. At Kotjahari, Rukum District, survival at 19 months was only 45 per cent, mean height 66 cm, and root-collar diameter 2 cm (N.K. Yadav and Thapa, 1989). Some of this apparently poor height growth may be due to browsing. In India naturally grown trees have a mean annual diameter increment of about 7 mm (Gamble, 1922). The mean survival rate in community forestry plantations in 1981 and 1982 was only 28 per cent (J.G. Campbell and Bhattarai, 1983b). Survival in private plantings was 47 per cent. Better results were obtained from farmers' planting in South Lalitpur (Hausler, 1990), where between 70 and 92 per cent survivors were recorded.

Uses

In most of the areas where it is known to farmers it is one of the most highly rated fodder trees. The leaves contain between 13 and 20 per cent crude protein with a high digestibility coefficient; according to R.V. Singh (1982) they are as good as legume fodder, and a little over 3 kg of leaves can be substituted for 1 kg of balanced concentrate. The trees are lopped mainly between mid-October and February, after which the leaves are shed. N.K. Yadav and Thapa (1989) recorded, in Rukum District, a yield (fresh weight) of 63 kg of fodder from trees averaging 11.1 m in height and 23 cm in diameter 30 cm from the ground, which is considerably higher than the 12–15 kg per tree in Himachal Pradesh reported by R.V. Singh (1982). In Dehimando, Mahakali Division, it constitutes about 11 per cent of the fodder trees owned by farmers (Hawkins and Malla, 1983). In south Lalitpur District it is important on north-facing slopes up

to 1750 m, and on south-facing slopes between 650 and 1000 m (Upton, 1990). It is only of minor importance in the areas of Dhading and Bara Districts studied by Upadhyay (1991) and is not mentioned for Lamjung District (K.P. Gajurel *et al.*, 1987). In Dolakha District it was absent from farmers' land, and none of them were interested in planting it (Robinson and Neupane, 1988). The wood is tough and elastic, and is used for tool handles and similar purposes. It weighs between 720 and 800 kg m⁻³, and it is a good fuel. However in view of the high value of the tree for fodder it is unlikely to be felled for wood. The bast fibre from one-year-old shoots, after they have been stripped of leaves for fodder, is used for making ropes. The fruit is edible.

Importance in Nepal

As already mentioned in some parts of Nepal it is a very valuable fodder tree and is often planted by farmers, sometimes on terrace risers. Like most fodder trees its importance varies considerably from district to district. Its performance in plantations has been rather disappointing, and as in addition the tree is liable to be damaged by browsing it would appear to be more suitable for planting by individual farmers, rather than in large-scale plantations.

References: M.W. Campbell (1983a); Ghosh (1977); Khatta and Katoch (1983); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Panday (1982); R.V. Singh (1983); J. Stewart (1983b); Troup (1921).

Grewia subinaequalis DC

(Syn. *G. asiatica* auct. non L.; *G. asiatica* var. *vestita* Wall. ex Masters; *G. vestita* Wall)

Nepali: syal phusro, phusro (also phusre, phasre, phosra), phalsa.

There is considerable disagreement between botanists on the nomenclature of this species, and its limits; as understood it is a tree which grows to a fairly large size, in which the leaves have five nerves at the base, rather than three as in *G. optiva*. *Grewia elastica* Royle is either the same species or a closely related one. It is also possible that some of the references to *G. tiliifolia* Vahl in Nepal belong here. This species is not included in the Check List, but occurs in adjoining parts of India, and may well occur here. The most obvious distinction is in its stipules which are leafy and fairly broad, whereas the other species have very narrow stipules. The Nepali names appear to apply to species of *Grewia* generally, and vary more with the region than according to the different species. In the account which follows there may well be more than one species in-

volved; it includes the shyal fusro from Dolakha referred to by Napier and Parajuli (1987) and most Nepal references to *G. tiliifolia*.

This species occurs up to about 1500 m. The seed is available in June to July; germination takes three to four weeks, and the plants need about a year in the nursery. It is subject to dieback, leaf necrosis, and defoliation in winter and is attacked by the leaf-spot fungus, *Cercospora grewii*. Height growth on cultivated, weeded and fertilized plots 18 months old at Hetauda was 1.5 m, with 96 per cent survivors, and at Chalnakhel 1.6 m, with 91 per cent survivors. Elsewhere recorded growth rates have been much slower. At Tistung (1900 m) it benefited greatly by having been planted under the shelter of pines. Unfertilized plants in the open had no survivors after 18 months, and fertilized only six per cent. Under pines the survivors were 56 per cent and 67 per cent respectively. The fertilizer used was 50 g Complexol (20:20:0) per tree. At Melechaur and Irkhu fertilizer reduced its growth under pines, which in any case was very poor, about 20 cm after 28 months. It is also a fodder species, the leaves of which contain 19.5 per cent crude protein, but it decreases milk yield and is not fed to pregnant or lactating cows. It is lopped between November and March (Panday, 1979; 1982), and also in the pre-monsoon period. A related species, phalsa in Nepali, is a large straggling shrub with globose fruit the size of a pea. The fruits are eaten fresh or made into beverages. It occurs in the far western Terai, and is perhaps the true *G. asiatica* L. (Regmi, 1982). Phalsa is widely cultivated in India for its fruits.

Guazuma Mill.

Sterculiaceae

***Guazuma ulmifolia* Lam.**

This species is native to tropical America from Mexico to Argentina, including the Caribbean Islands. It is usually found at altitudes below 1100 m, with an annual rainfall of 1000–2000 mm, five to six dry months a year (rainfall 100 mm) and average temperatures between 20 and 30°C. It was introduced into Nepal from La Trinidad, Nicaragua, in 1985. It is showing considerable promise in the Bhabar Terai.

Nursery techniques

There are about 170,000 viable seeds kg⁻¹. After being wetted they produce a mucilaginous jelly, which may inhibit germination; this can be removed by pouring five volumes of boiling water over the seed, leaving it for 30 sec, and

then draining it off. In trials this method gave 87 per cent germination after four weeks. Treatment with cold water or water at 60°C gives poor results. Without the boiling water treatment germination is very sporadic and extended over many months.

Early nursery trials in Nepal were affected by poor and sporadic germination due to lack of the treatment described above. Seed was sown in trays and the seedlings were pricked out into polythene containers when between 1.5 and 2.5 cm tall. After 4.5 months seedlings 15 cm tall with a root-collar diameter of 3.5 mm were produced, rather below optimum size but large enough for a plantation trial to be made. If prompter germination had been obtained the mean height of the seedlings would probably have been higher.

Performance in plantations and rate of growth

At low elevations survival and growth have been very promising. At Adabhar in the Bhabar Terai (170 m) trees 17 months old averaged 3.9 m in height and 3.5 cm dbh. At 4.3 years the average dbh was 7.1 cm, and an average of 10.1 kg green matter per tree was produced from lopping. Another trial four months later from trees of mean diameter 9.4 cm yielded 8.9 kg tree⁻¹ (S.M. Amatya, 1992). In well-maintained young plantations, grass is rapidly eliminated. At higher altitudes however growth has been much slower, less than 40 cm after three years at 1000 m. Above this altitude survival has been poor or nil. Thus the species is only suitable for altitudes below about 500 m. The tree coppices and pollards well.

Uses

Green leaves contain 95 per cent total dry matter and 17 per cent protein (Salazar and Quesada, 1987). In Latin America they are said to be highly palatable to livestock, though in Nepal cattle have initially shown some reluctance to eat them. The fruit is eagerly eaten by cattle; humans can also eat it. The wood is a good fuel.

Heynea trijuga see *Trichilia connaroides*.

***Ilex* L.**
Aquifoliaceae

***Ilex excelsa* (Wall.) Hook. f.**

(Syn. *I. doniana* DC)

Nepali: puwanle, puwale, bhokre.

A medium-sized, evergreen tree growing to about 15 m. Leaves alternate, simple, leathery, dark green and shiny, without teeth or spines, 5–10 cm by 2.5–5 cm, on stalks 1.2–2.5 cm long; lateral veins arched. Flowers greenish-white, about 4 mm across, in umbels in the leaf axils. Fruit a bright red globose drupe about 1 cm in diameter. It is found in Nepal between 600 and 2100 m. The fruit ripens between July and September in the Kathmandu Valley. There are 70,000 seeds kg⁻¹, which can be stored for three years in sealed containers. The seed needs exposure to cold before it will germinate; this can be achieved by mixing it with sand, and leaving in an exposed position over winter. Even so germination is irregular and may take two years. Growth in the nursery is very slow; the seedlings may need to be kept for a year before they are pricked out, and as long as four years altogether in the nursery. Its main use is for fodder; the leaves contain about 10–11 per cent crude protein. It has been suggested for use as a hedge. Nine other species of *Ilex* occur in Nepal.

References: M.W. Campbell (1983a); Panday (1982).

***Indigofera* L.**
Papilionaceae

A very large genus, mostly of herbs and shrubs, with a few species reaching tree size. Leaves pinnate; leaflets with two-branched hairs. Flowers often rose or purple. Fruit a pod.

***Indigofera teysmannii* Miq.**

(Syn. *I. zollingeriana* Miq.)

A native of Sri Lanka and Indonesia, originally introduced to Nepal as a shade tree for tea in eastern Nepal, and since tried out as a fast-growing fuelwood species, for which it shows promise. It branches near the ground into several

stems, and produces a low-spreading canopy, which rapidly suppresses grass. It nodulates freely and fixes nitrogen. Flowering and seed set at the age of 18 months has been recorded in the Bhabar Terai zone. It appears to coppice well. In one trial the production of new shoots after pollarding was poor, but infection by *Ganoderma* (see below) may have influenced this.

It can be raised in polypots, by sowing two seeds previously soaked in water for 24 hours in each pot, two or three months before the monsoon. Stumps have not been successful. Direct sowing is possible.

It has been included in a number of trials, both pure and in mixture with other species. The first was at Adabhar in 1984 where after 18 months trees planted at 1.5 m x 1.5 m had reached a mean height of 4.7 m and dbh of 3.3 cm. The green weight of fuelwood per tree was 9.1 kg, and there were 100 per cent survivors, giving a fuel green weight of about 40 t ha⁻¹. All grass had been eliminated (Hawkins, 1986). A trial planted two years later was not quite as successful. At 2.8 years old the mean height was 4.85 m, and mean diameter at 30 cm from the ground 4.4 cm, but survival was only 60 per cent, and some trees were infected by the bracket fungus *Ganoderma endochroum*. Other trials gave the following results: Adabhar, Bara District: age 19 months, height 4.8 m, dbh 8 cm (stoutest stem per plant), planted 2 m x 2 m. Sarlahi District: age 15 months, height 5.5 m, dbh 6.8 m.

It has also been tried in mixture with other species, partly to provide nitrogen and partly to suppress grass growth and reduce weeding costs, in which it has been very successful. At Adabhar it was interplanted in *Eucalyptus camaldulensis* and *Acacia catechu* plots. At the age of 33 months the *Indigofera* was pollarded at 1 m from the ground; in the *Eucalyptus* plot this yielded 6.8 t ha⁻¹ oven-dry weight of fuel, or the equivalent of 2.5 t ha⁻¹ yr⁻¹, not, of course, including the one metre long stems left after pollarding. At Tamagadhi a mixture of *Acrocarpus fraxinifolius* and *I. teysmannii* was planted at 2 m x 2 m spacing, with alternate plants of each species. Twenty-six months after planting the *Indigofera* had produced the equivalent of a mean annual increment of 10.6 t ha⁻¹ of oven-dry wood, while the *Acrocarpus* had produced 4.6 t ha⁻¹. At Butwal, *I. teysmannii* was interplanted at different spacings and configurations between *A. fraxinifolius* planted at 4 m x 2 m. Best results were obtained from a single row of *Indigofera* half way between the rows of the *Acrocarpus*. Other treatments resulted in the suppression of the *Acrocarpus* by the *Indigofera*, which grew to 1 m tall four months after planting.

In addition to its use as shade for tea, it has been used for windbreaks at the medicinal herbal farm at Tamagadhi, and in alley cropping schemes. It gave mixed results when planted as a roadside tree on denuded sites, failing on the most exposed sites. Other plots at Adabhar, in addition to the one mentioned

above, have been attacked by *Ganoderma*, which can cause numerous deaths. So far no records have been seen from other sites.

The density of the wood is 575 kg m⁻³. The leaves are not palatable and contain a skin irritant, so it has no fodder value (Hawkins, 1986). It shows promise as a quick-growing fuel species for the Terai and Bhabar Terai zones, and for controlling grass, but fungus attack may give cause for concern.

References: M. Karki (1992); Neil (1990d; 1990h; 1990k); M. Thapa (1990a).

***Jacaranda* Juss.**

Bignoniaceae

***Jacaranda mimosifolia* D. Don**

(Syn. *J. ovalifolia* R. Br.)

Newari: chakhoondha swan.

Deciduous tree. Leaves opposite, bipinnate, with numerous small leaflets. Flowers blue, in great masses. Fruit round, woody and flattened, about 5 cm across, containing numerous seeds. This tree, a native of Brazil, was introduced to Nepal many years ago as an ornamental and avenue tree, and has been widely planted in the Kathmandu Valley and elsewhere. It can be planted from the Terai up to about 1600 m. The fruit is collected in February and March, and dried in the sun to release the winged seeds. There are about 50,000 seeds kg⁻¹, and they can be stored for up to two years. The germination percentage is about 50. The seed can either be sown directly into polypots, or in beds and later pricked out. The tree can also be propagated from the suckers arising from the base of the stem. It has been raised in community forestry nurseries on a small scale for issue as an ornamental to farmers.

References: M.W. Campbell (1983a); Lamichhancy and Joshi (1980); Storrs and Storrs (1984); Streets (1962).

Juglans L.

Juglandaceae

Juglans regia L.b

Nepali: okhar.

Walnut.

Tree. Bark of old trees deeply fissured. Leaves alternate, pinnate, with 5–13 pointed almost hairless leaflets, without teeth on the margins. Male flowers in long drooping catkins; females single or two to three together at the ends of young shoots. Fruit green, spherical to oblong, about 5 cm long, containing a wrinkled two-valved nut. The indigenous walnut with a rather small thick-shelled fruit (hade okhar) is var. *kamaonia* C. DC. Fairly recently the kaghazi (paper-shelled) walnut, called dante okhar, has been introduced from Kashmir. The techniques of cultivation are similar for both.

Natural occurrence

Walnut is found in Nepal from 1200 to 2500 m, and its longitudinal range covers the whole country. West of the Dhaulagiri massif it is a constituent of *Quercus leucotrichophora* forest, typically in moist sites near streams. It also forms an association with *Aesculus indica* and *Acer* species, between 1800 and 2800 m, in the west midlands, the Humla-Jumla area, and some of the inner valleys in the west. Further east it is associated with *Quercus lamellosa* forest, between 2000 and 2600 m. It tends to occur either in higher rainfall areas, or in moister sites in lower rainfall areas. In the Far Western Development Region walnuts have frequently been planted by villagers, but this is not a tradition in central and eastern Nepal. Outside Nepal var. *kamaonia* extends from Kashmir to Bhutan, the Khasi Hills, and southern Tibet. The species as a whole extends naturally as far west as southeast Europe, and has been widely planted elsewhere in Europe and America.

Silvicultural characteristics

A large, deciduous, light-demanding tree. It occurs naturally on rather moist sites, especially on deep, well-drained, bouldery alluvium near streams. It does not grow well on stiff, badly drained or acid soils, nor in exposed windy situations. The seedlings may suffer from early or late frosts when they are in leaf, but in the dormant state when they have shed their leaves they are more resistant. The trees need a certain amount of winter cold if they are to produce fruit; hence they should not be planted below 1200–1300 m. It coppices well.

Natural regeneration

This is often poor, partly due to the seeds being eaten by rodents and other animals. The seeds fall to the ground under the trees and for germination to be successful they need to become covered lightly with soil or other debris. Regeneration is often plentiful on bouldery slopes with loose, but fairly deep, moist soil.

Artificial regeneration

The seed ripens between September and December, with the date of ripening later in the west than in the centre or east of the country. It is generally necessary to buy nuts on the market. The number of nuts kg^{-1} ranges from about 35 to 120; those of dante okhar are larger and heavier than those of the local variety. The seed is recalcitrant, and must not be allowed to dry out. It can however be stored for a year or more if kept moist, cool and aerated. This can be done by soaking the nuts for 24 hours, mixing them with 2–4 times their volume of damp sand, and placing them in a fine wire mesh bag, or a clay pot with a lid, and burying them in a pit 1–1.5 m deep. The seeds need a period of cold, moist stratification before they will germinate. If they are soaked in water for 24 hours and sown at the time of collection they will not germinate until about February of the next year, and thus will be stratified naturally; however during this period they are very liable to be eaten by rodents and other animals. Thus it may be better to store in pits as described above. If the seeds are not sown immediately after collection they should be sown in February in large (10 cm x 18 cm lay-flat, or larger) polypots, with the nut horizontal, and lightly covered with soil. A fertile, well-drained potting mixture, containing 20–25 per cent compost, should be used. In the laboratory 65 per cent germination has been obtained, but in nurseries between 30 and 50 per cent is more usual. The strong taproot development of *J. regia* means that sowing into beds and later pricking out is not to be recommended. Frequent root pruning and spacing is important. At all stages protection against rodents is very important. The growth of the seedlings in the nursery is fast and in nurseries below 1500 m seed sown in February will produce plants 25–30 cm tall by the onset of the monsoon. *Juglans regia* has a marked dormant season in which even small seedlings drop their leaves. Hence, at higher altitudes on moist sites it can be established by planting in winter, and bare-root stock can be used for this purpose. At Charikot (2200 m) bare-root stock planted in February gave 85 per cent survival.

Troup (1921) states that the use of stumps with a one-inch (2.5 cm) stem and nine-inch (22.5 cm) root has been successful, and this technique would be well worth trying in Nepal. To raise stumps the seeds should be dibbled into beds at

a spacing of about 6 cm x 6 cm. Direct sowing, either into prepared pits, or by dibbling in the seed, has been used in India. If snow can be relied on, direct sowing before the snow falls is recommended, but there are relatively few places in Nepal with reliable winter snowfall. The main difficulty in direct sowing is the danger of losses not only from the depredations of squirrels and other rodents, but also from small boys, who will dig up and eat the seeds. In Nepal the use of nursery-raised plants is safer. For fruit production the use of grafted or budded stock is preferable, using whip grafting or patch or T-budding. Dante okhar can be successfully grafted on to the indigenous variety, and if this is done fruit is produced earlier than if it is grown on its own rootstock. Attempts to propagate it by hardwood cuttings at Hetauda failed; new shoots were put out but the cuttings failed to root. It is reported that hardwood cuttings 1 cm in diameter and 30–50 cm long, taken in January or February, will root if set horizontally in a trench 10 cm deep. *Juglans regia* for nut production should be planted at a wide spacing, about 10 cm x 10 m. For intensive production pruning, fertilizing, and other cultural treatment are necessary. For these techniques horticultural textbooks should be consulted such as Childers (1966).

Performance in plantations and rate of growth

Fairly good results were obtained at 1750 m in Sankhuwasabha District, on a dark moist fertile soil with a westerly aspect, where trees three years old averaged about a metre in height (Sizeland, 1986). At Salle, in the same district (2000 m), there was 92 per cent survival and the trees averaged 56 cm high, though the tips had been damaged by frost (Sherpa *et al.*, 1992). At Simkhara (2400 m) at 2.4 years old, though survival was moderately good (65 per cent) the mean height was only 10 cm. The trees failed at Tistung (1900 m); Murtidhunga (1500 m); and Thulo Chaur, Mustang District (2550 m).

Results in community forestry plantations have been poor. Average survival in the plantations studied by J.G. Campbell and Bhattarai (1983b) was only 27 per cent, though it was slightly better next year, at 40 per cent. In Lalitpur District survival of trees planted by farmers on their own lands was generally poor (15–38 per cent) with the exception of one village in one year when 88 per cent survival was recorded. In the next year this village also had poor results. *Juglans regia* if planted on unsuitable sites often stagnates. It drops its leaves but may remain alive for two or three years.

In India the mean annual diameter increment is about 1.6 cm for planted trees in the Sikkim Himalaya, 0.8 cm for natural trees in the same region, and 0.34 for trees in the western Himalaya.

Uses

The most important product from the *Juglans regia* is, of course, its fruit. This is especially important in the hills of western Nepal where the nuts, in addition to being eaten whole, are used as a source of cooking oil. The bark and leaves have medicinal uses. The wood is even-grained, greyish brown with dark brown streaks and is highly valued for furniture and gunstocks.

Importance in Nepal

This is pre-eminently a tree for farmers to plant near their houses as a source of nuts and oil. Larger-scale plantations should be managed on fruit orchard rather than forest plantation lines, using grafted trees and intensive tending.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Napier and Robbins (1989); J. Stewart (1983a); Streets (1962); Suri and Seth (1959); Trotter (1958); Troup (1921).

Juniperus L.

Cupressaceae

Juniperus species

Nepali: dhupi. (Dhupi is a general name for trees resembling *Juniperus* in their leaves, including also *Cupressus* species and *Cryptomeria japonica*; it derives from the Nepali word for incense.)
Juniper.

Two species of *Juniperus* attain tree size in Nepal, *J. indica* Bertol. (*J. wallichiana* Hook.f. and Thoms., *J. pseudosabina* auct.), and *J. recurva* Buch.-Ham. ex D. Don (*J. macropoda* auct.). Two other species are low shrubs, *J. squamata* Buch.-Ham., and *J. communis* L. var. *saxatilis* Pallas. However the species which can grow to tree size often occur also as low tussocky and prostrate shrubs, especially at higher altitudes and in dry places. The following key is adapted from Hara *et al.* (1978).

- (1) Leaves boat-shaped, spreading, free from the branchlets for 10 mm of their length, with a broad white band on the back *J. communis* var. *saxatilis*
- (1) Leaves scale-like or needle-like, usually clasping the branchlets, with 5 mm or less free; bands if present inconspicuous 2

- (2) Leaves on the branchlets up to 1.5 mm long, closely clasping the stem, those on main shoots needle-like, in threes, 4–5 mm long; fruits ovoid, blue-black *J. indica*
- (2) Leaves all of one kind, 2 mm or more long, points free from the stem; fruits almost spherical, ripening black 3
- (3) Shrubs or small trees; growth rather loose and shoots tail-like, curving; fruits purplish-brown to black *J. recurva*
- (3) Prostrate shrubs; growth tight, only leading shoots separate from the mass; fruits reddish-brown to black *J. squamata*

Both *J. indica* and *J. recurva* are plants of high altitude; the former extends from 2700 to 4700 m, and the latter from 3600 to 4600 m (T.B. Shrestha, 1984a). They often form a sort of scrub vegetation above the upper limit of the forest. *Juniperus indica* is the last tree species to survive as the rainfall gradually decreases to the north of Jomsom, and thus is the most drought-resistant tree growing naturally in Nepal. *Juniperus*, unlike many other conifers, will coppice, provided the trees are not too large.

The month in which the seed ripens appears to vary a great deal. In the Langtang Himalaya plants were recorded in fruit between April and July (*J. recurva*), and in June and September (*J. indica*) (Department of Medicinal Plants, 1976). However, ripe fruit of both species was recorded in October and November in the mountains east of the Arun River (Lancaster, 1981). *Juniperus recurva* has about 3600 seeds kg⁻¹.

The seed needs cold stratification over winter before it is sown, and even after that germinates very irregularly; it may take up to two years. Germination may be speeded up by soaking the seed in hot water for a few minutes (Dallimore and Jackson, 1948). It can be stored for up to 20 years. For raising seedlings the seed should be sown in trays, and the seedlings pricked out into plastic tubes when they reach a height of 2–3 cm. A more rapid way of raising planting stock is by the use of short side cuttings taken in October and November, and stuck into sand under a polythene cloche. However, some species although rooting quite well, take rather a long time, up to 3–4 months. Growth is very slow, especially in the inhospitable sites where they are mainly found. Sikkim specimens of *J. recurva* had a mean annual diameter increment of about 2.4 mm, and western Himalayan specimens about half this (Gamble, 1922).

Juniperus is often the main source of fuelwood where it occurs, and in places has been severely exploited for this purpose. The wood is an excellent fuel and will burn when still green. It is also used as incense. The timber is of high quality, being aromatic, easy to work, and very durable. Juniper wood is preferred for making lead pencils. However large trees in Nepal are too scat-

tered and too remote for the timber to be much used. The berries are medicinal and used in flavouring; about 50 t are collected annually, especially in Dolakha District (Natural Products Institute, n.d., Bulletin 33).

Although an important source of fuel where they occur, their very slow growth reduces their value as plantation species; priority should be given to the protection and management of natural stands rather than the formation of plantations.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Troup (1921).

Justicia L.

Acanthaceae

Justicia adhatoda L.

(Syn. *Adhatoda vasica* Nees)

Nepali: asuro, assara, kalo bhashak.

Usually a shrub 1–2 m high, but occasionally growing to a small tree about 6 m high. Leaves opposite, almost glabrous, ovate-lanceolate, 12–20 cm long, on stalks 1.2–2.5 cm long. Flowers white with red spots, in compact spikes, each with a bract 1.5–2.0 cm below it. Capsule club-shaped, about 2 cm long, containing four seeds. It is found on waste ground between 500 and 1300 m, being commoner at the lower altitudes. It owes its abundance to its being unpalatable to grazing animals, which often keep it down to a shrubby state. It occurs as an understorey in *Shorea robusta* forest in some places, and is tolerant to shade, but will survive on dry, stony sites. It can be propagated by seedlings or cuttings. Cuttings 1.5 m long, buried 30 cm in the ground, were used for live fences and erosion control in the Tinau Watershed Project (Schaltenbrand, 1982), and stem cuttings, either planted direct or rooted in the nursery have given a high success rate when used to stabilize road banks (Howell *et al.*, 1991). It is included as a possible fuelwood crop in National Academy of Sciences (1980), but has the disadvantage of burning rather quickly and producing an irritant smoke (Chaturvedi *et al.*, 1986). In addition to its possible use as fuel, the leaves and roots are used in traditional medicine, and are collected for sale.

Reference: Bahuguna *et al.* (1987b).

Lagerstroemia L.

Lythraceae

Lagerstroemia parviflora Roxb.

Nepali: ashare, ashare phul, lendia, bot adheyaro, (bhoddaire, buddhi dhaiyare, etc.).

Large tree. Bark light brown, peeling off to leave lighter patches. Leaves opposite, 5–10 cm long, stalkless or on very short stalks. Flowers small, white, fragrant, in panicles in the leaf axils or at the ends of the branches. Fruit oval, about 2 cm long; base enclosed in a cup formed by the persistent calyx.

Natural occurrence

Found in the Terai and Bhabar Terai zones of Nepal, and a common constituent of *Shorea robusta* forest and related types. It ascends to about 1200 m. Outside Nepal its range is from Kumaon to Sikkim and Burma.

Silvicultural characteristics

It is a large, deciduous, light-demanding tree. The seedlings are killed by severe frosts, but older trees and coppice shoots are frost-resistant. It grows on a variety of soils, including Terai and Bhabar Terai soils, but does not thrive on waterlogged soils. It is not browsed by cattle, and recovers well after fire. The tree coppices and pollards well.

Natural regeneration

Abundant fertile seed is not produced every year. The capsules remain on the tree after ripening, and shed the winged seeds. Reproduction is best on loose porous soil, such as abandoned cultivation and riverain gravel which has risen above river level. The freedom from browsing by cattle, and good recovery after fire, favour it over more susceptible species.

Artificial regeneration

The fruits ripen during the dry season, but in India the seed produced was only found to be fertile in one year out of three (Troup, 1921). There are between 30,000 and 60,000 seeds kg⁻¹. According to M.W. Campbell (1983a) germination from seeds two and three years old is better than that from fresh seeds: fresh seeds ten per cent; three-year-old seeds 40 per cent. The seed should be sown in trays or beds and the seedlings pricked out into polypots when they are 5 cm tall. They will reach a height of about 30 cm after one year in the nursery.

Stumps prepared from plants one to two years old, can also be used. It is also possible to propagate this species from hardwood cuttings taken when the tree is leafless (February to March); they should be 12–15 cm long and 5–8 mm diameter. They are lined out in beds when they are taken, and can be planted during the next monsoon.

Uses

It produces a valuable timber, which in India is rated after *Shorea robusta* and *Terminalia alata* in the areas where it is found. It is used for building construction, door and window frames, carts and agricultural implements. It is an excellent fuel (weight about 850 kg m⁻³) and makes very good charcoal. The leaves are not palatable to cattle (Storrs and Storrs, 1984), but in India they are lopped for buffalo fodder (R.V. Singh, 1982). They contain about eight per cent crude protein, which is rather low, and about 50 per cent total digestible nutrient.

Importance in Nepal

The tree is felled for timber where it occurs naturally, but up to the present it has rarely been planted. Its growth is slow, but its good qualities as a fuel and its relative immunity to browsing might justify trials on a small scale in the Bhabar Terai and Terai. Volume and biomass equations are included in E.R. Sharma and Pukkala (1990a; 1990b).

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); R.V. Singh (1982); Trotter (1958); Troup (1921).

Two other species of *Lagerstroemia* are planted in Nepal as ornamental trees. *Lagerstroemia indica* L. (Newari: sina jya swan) is a shrub or small tree with crinkled white, pink, or purple flowers 2.5–4 cm across, often planted in streets. *Lagerstroemia reginae* Roxb. (*L. flos-reginae* auct. non Retz.) is a large tree with pink to purple flowers about 7 cm across, flowering in the hot season. Both species are also called ashure phul in Nepali.

Lannea A. Rich.

Anacardiaceae

***Lannea coromandelica* (Houtt.) Merr.**

(Syn. *L. grandis* (Dennst.) Engl.; *Odina wodier* Roxb.)

Nepali : jhingat, dabadabi, bara, hallongre.

Large tree with spreading crown. Bark light grey, exfoliating in thin irregular plates in older trees. Leaves alternate, pinnate, with 5–11 shortly stalked ovate or lanceolate leaflets 6–15 cm by 2.5–8 cm. Flowers pale yellow, 4–5 mm in diameter, in long slender inflorescences crowded towards the ends of the leafless branches. Fruit oblong, fleshy, red when ripe. It is found from the Terai to 1400 m in open places in *Shorea robusta* forests and the mixed forest in the lower hills. It is a strong light-demander, and does not stand shade and competition well. It is frost-tender and very subject to browsing, but resists fire well. It tolerates soil with a high pH. Its root system is very deep and it grows well on sandy soils and the bunds of farm terraces.

Farmers propagate it by hardwood cuttings; the following account of the methods they use in the Rapti zone is based on Chapa (1992). The cuttings are 90 to 180 cm long by 2.5–3 cm in diameter, and are cut straight across, care being taken not to tear the bark or harm the meristematic tissue. They can be stored 30–45 days before planting if kept under shade in a cool, dry place. Larger cuttings, 1.5 m, are planted in 45 cm pits; 90 cm cuttings in 30 cm pits. In some places, to protect against termites, about 20 g of ash or rice husks is put in the bottom of the pit; it is not mixed with the soil. Planting takes place from December to March (Paush to Phalgun); care is taken that the soil is moist at the time of planting. The cuttings are planted upright, with about a third of their length buried. If the bark of the cuttings is damaged during transportation the wound is treated with a mixture of cattle dung and mud, and tightly covered with plastic. Great care is taken to avoid shaking or jarring the newly planted cuttings, and cattle are kept out of the planted area. New leaves appear during May and June, after which the farmers believe that the trees are out of danger. The seed ripens between May and June; it is said to lose its viability rapidly. There are between 5500 and 10,000 seeds kg⁻¹. In India it has been successfully established by using one-year-old stumps from 45 cm high nursery stock; after one year, plants were up to 120 cm tall, with 80–90 per cent survival. Trees planted from large cuttings will begin to yield fodder from the third year after planting. The trees are said to reach maturity after 20 years.

Its main value in Nepal is for fodder. In the Madi river basin it is the fodder tree most preferred by farmers, who prize it for its rate of growth, coppicing capability, yield in fodder and fuelwood, and frequency with which it can be lopped. It is leafless from soon after the monsoon until May or June, and is lopped twice a year, with the first lopping in mid-June to mid-July. Farmers state that the average yield of fodder is 20 kg tree⁻¹. It also produces 5–15 kg of fuelwood per tree, though it is not considered a good fuelwood as it contains a lot of water. It is mainly used for fodder at low elevations, and is not included in the lists of fodder trees from Lalitpur, Bara and Lamjung Districts.

References: Chapa (1992); H.B. Joshi (1980); Troup (1921).

***Larix* Mill.**

Pinaceae

Larch

***Larix griffithiana* Carr.**

(Syn. *L. griffithii* Hook. f. and Thoms.)

Nepali: talis patra, bogre salla.

Deciduous tree with long pendulous branches. Leaves needle-like, in whorls of 10–50 on short lateral shoots. Mature cones about 8 cm long by 3 cm in diameter, with long pointed bracts emerging between the leathery cone scales. It occurs in Nepal in a small area to the east of the Arun River between 2500 and 3500 m. In central Nepal, for instance the Langtang valley, it is replaced by another species identified as *L. himalaica* Cheng and Fu, which differs in its shorter cones and bracts which do not protrude beyond the cone scales. The taxonomy of this tree is rather confused and it has been considered by some authors to be a form of *L. potanini* Batal. For discussion see T.B. Shrestha (1984a).

Larches occur in deep valleys but prefer well-drained rocky slopes such as ancient moraines. *Larix himalaica* appears to be slightly more drought-resistant than *L. griffithiana*. The cones ripen about October; there are about 100,000 seeds kg⁻¹. The seed is extracted by drying the cones in the sun. It may be sown when collected, and left to naturally stratify in the nursery bed until March or April, when it will germinate; otherwise it can be stored in a cold place until spring and sown then. Plants will probably need at least 15 months in the nursery after the seed has germinated. The growth of natural trees is slow, with

about 2.4 mm annual diameter increment. Larch produces a useful durable timber, weighing about 510 kg m³.

References: M.W. Campbell (1983a); Gamble (1922); Troup (1921).

Exotic species

Larix decidua Mill., European larch, *L. kaempferi* (Lamb.) Carriere, Japanese larch, and *L. occidentalis* Nutt. from the northwestern United States have also been introduced. There are no records of their subsequent fate.

Leucaena Benth.

Mimosaceae

Unarmed trees or shrubs with bipinnate leaves, with glands on the rachis. Flowers small, in globose heads; stamens ten. Until a few years ago *Leucaena* species, especially *L. leucocephala*, showed great promise in Nepal as a source of fodder and quick-growing fuelwood. Since the arrival of the *Leucaena* psyllid the prospect is much more uncertain. It is to be hoped that before long, answers will be found to the psyllid problem but until then planting of *Leucaena* should be restricted to trial plots, and large-scale planting discouraged. In addition to *L. leucocephala* a number of other species and hybrids have been introduced, partly to find psyllid-resistant cultivars.

Leucaena leucocephala (Lam.) de Wit

(Syn. *L. glauca* (Willd.) Benth.)

Nepali: ipil ipil.

Origin

Leucaena leucocephala is native to Central America, from Mexico to Honduras, and also occurs in Peru. A low, shrubby type of Mexican origin was introduced to south Asia probably at least a century ago, and has been collected in Nepal. Much more recently giant arboreal types, which can grow into large trees, have been introduced from Salvador and Guatemala. Trees of different origin vary considerably in their growth, silvicultural requirements, and tolerance or resistance to psyllid attack; hence variety is most important (see below).

Silvicultural characteristics

The giant arboreal types of *Leucaena* are trees capable of growing to 20 m in height. They are normally evergreen, but will shed their leaves during periods of prolonged drought or frost. They will tolerate partial shade, but grow best in full sun. Most cultivars tried grow best below 1000 m; at higher altitudes they may survive, but growth is likely to be poor.

Leucaena is sensitive to soil pH and where this is less than five growth is seriously reduced (Ahmad and Ng, 1979). It is also sensitive to relatively small differences in soil fertility, and within the same plantation very vigorous trees may be found growing within a few metres of poor stunted ones. In the constantly humid tropics, such as in the Philippines, it has been used successfully for reafforestation of denuded slopes, but in areas with a pronounced dry season it requires soils of at least moderate fertility. In Nepal it generally grows well on Bhabar Terai soils, but has failed on very gravelly and bouldery soils near rivers, though these soils are capable of growing good crops of *Dalbergia sissoo* and *Acacia catechu*. More needs to be learned about the tolerance of different *Leucaena* cultivars to different soils and altitudes in Nepal.

In the constantly humid tropics, such as in the Philippines, *Leucaena* will compete with and eventually dominate *Imperata* grass, but this is not the case in drier areas such as Nepal, where thorough weeding is necessary if successful plantations are to be established. Young seedlings are killed by frost, and the tree should not be planted in frosty areas. They are very palatable to grazing animals including deer, and it is not practicable to plant *Leucaena* in areas where wild game is abundant, as the cost of erecting deer proof fences is prohibitive. Trees are fairly resistant to fire, but repeated fires will kill them.

Flowers and seed are often produced at a very early age, often less than a year. According to Hawkins (1986), at Adabhar in the Bhabar Terai varieties which flowered early also suffered from up to 1 m shoot dieback during the dry season, while those which did not flower before 18 months avoided this.

The seedlings and older trees have very strong taproots. Rhizobial nodules which fix nitrogen are found on the roots, and if the appropriate strain of the *Rhizobium* bacterium is absent growth is considerably reduced. In some parts of Nepal inoculation by *Rhizobium* may occur naturally from bacteria within the soil, but this cannot be relied on and artificial inoculation in the nursery is a necessary safeguard (see Inoculation, page 597). *Leucaena* coppices very readily. Even if stems little over 1 cm in diameter are cut, the roots will frequently send out new shoots.

Artificial regeneration

Seed

As noted above many varieties of *Leucaena* seed prolifically from a very early age. They often produce seed almost all the year round, but November to January have been recorded as the months for seed collection in Nepal. There are 20,000 to 26,000 seeds kg⁻¹. The seed can be stored for many years without losing its viability; indeed seed stored in Paris at room temperatures still gave some germination after 99 years (Barton, 1961). It should be dried and stored in sealed containers, and a little contact insecticide should be mixed with it, as it is very liable to borer attack during storage.

The seed has a hard impervious coat and needs treatment before it is sown, otherwise germination may take many months. Small quantities of seed may be manually scarified by cutting off a small portion of the coat at the opposite end to the hilum; Napier (1987c) found this the most effective method, giving more than 80 per cent germination within eight days.

For larger quantities this is very laborious, and hot water treatment may be used instead. Water is brought to the boil, removed from the heat, and the seed kept in it for 2–3 minutes before being soaked in cold water for 24 hours. Alternatively it may be soaked in water at 80°C for two minutes, and then put in cold water as before. Napier found that treatment with hot water for five minutes caused about 12 per cent of the seedlings to imbibe water. These imbibed seeds had lower germination; combined germination of imbibed and non-imbibed seeds was 78 per cent after 20 days. Keeping the seed in boiling water for five minutes reduced germination.

Inoculation

The standard method of inoculation of *Leucaena* seed is by the use of *Rhizobium* culture, which it may be possible to obtain from the Department of Agriculture, Khumaltar. Different strains of *Rhizobium* are available for neutral or alkaline soils, and for acidic soils. The *Rhizobium* culture is mixed with an adhesive such as two per cent gum arabic solution, and the seeds are coated with this mixture. This treatment should be applied after the seeds have been treated with hot water. After coating with inoculum the seeds are dried, and they should then be sown within week. If it is impossible to obtain *Rhizobium* inoculum, soil should be collected from beneath vigorous *Leucaena* trees and mixed with the potting mixture. This method was used successfully in Hetauda nursery, using soil from well-grown *Leucaena* at Nijgad. The soil used for inoculation should if possible come from trees growing on a similar soil type to that on which the *Leucaena* will eventually be planted.

Nursery techniques

The potting mixture used for raising seedlings should not be more than slightly acid; preferably the pH should be six or more. The seed should be sown directly into polythene bags, and any surplus seedlings pricked out into empty pots soon after germination is complete. For raising plantable stock 8–10 weeks in the nursery will be needed in the Terai, and 10–12 weeks in the inner Terai. Above 1000 m *Leucaena* will rarely be raised in nurseries. No shade is needed. The seedlings rapidly develops a strong taproot, and frequent and regular root pruning, every 10–14 days, is essential. If the taproot has once been allowed to develop, drastic root pruning is likely to kill the seedlings, even if the shoot is reduced at the same time (J. Stewart, 1983a).

In some nurseries seedling growth has been very slow. Some of these were at high altitudes, where slow growth is to be expected, but slow growth was also recorded at some low-altitude nurseries, despite hot water treatment of the seeds. It is possible that this was due to lack of inoculum, to an unsatisfactory potting mixture, or to an unsuitable variety. *Leucaena* can also be established by using stumps.

Plantations

As has been previously pointed out plantations need thorough weeding until the trees have become established. For fuel and fodder plantations, planting at a close distance, such as 1 m x 1 m, could be tried. Depending on the growth of the trees, during the second year after planting alternate trees or rows of trees could be coppiced or pollarded for fodder and small fuelwood, and the shoots from the cut stems from then on be cut regularly for fodder, leaving the remaining trees to grow on for fuelwood production. Young plantations need careful protection against browsing, as has been noted earlier.

Direct sowing

Although *Leucaena* plantations have been successfully established by direct sowing in many parts of the world there are problems in using this technique. The main one is that early growth of the seedlings from seed sown directly in plantations is slow. It may take a year in the plantation to obtain the same height growth as is reached in two months in the nursery; meanwhile the seedlings need very thorough weeding. Unless *Leucaena* is raised in conjunction with agricultural crops the use of seedlings raised in polythene pots is more reliable.

Pests and diseases

Of these by far the most important is the psyllid *Heteropsylla cubana*, sometimes known as the jumping plant louse. L. Joshi (1990) has given an account of its arrival in Nepal. This pest reached Hawaii in 1984, and from there has

spread south and west, reaching Nepal probably around April 1989. By July 1989 there was heavy infestation between Dharan and Dhankuta in eastern Nepal, and by August a few insects were found in Hetauda and Pokhara. As the insect is spreading from east to west it is likely that most parts of Nepal will be affected eventually. The nymphs feed on the newly developing shoots and young leaves, covering the new leaflets with a sticky exudation. This often leads to the dieback of new shoots and may sometimes kill the whole tree. There are some indications that, after an initial severe attack, later damage by psyllids may be reduced after one or two years. This may be due to local predators and parasites multiplying and adapting to feeding on this new food source. To what extent this will happen in Nepal remains to be seen. At present in some parts of the Terai well-grown trees appear to be still vigorous, though young trees may suffer from psyllid attack. It may be that eventually at least some varieties of *Leucaena* may be found to grow satisfactorily despite psyllid attack, though perhaps with some loss of increment. More investigation is needed on such varieties (see Varieties and cultivars, below).

Insecticides are generally ineffective for long-term psyllid control, though they may be effective in nurseries. They also may eliminate predators and parasites, along with the pest, and many are hazardous to the environment. There are possibilities of biological control, including the beetle *Curinus coeruleus* and the wasp *Psyllaephagus* sp. There are always dangers in introducing biological control agents, in that the predator or parasite may spread to other species than those it was hoped to control, and initial introductions should be investigated under controlled conditions before being released into the environment at large.

The fungus *Ganoderma endochroum* has occasionally caused heavy mortality in plantations; it spreads from the stumps of trees felled in natural forest. Gummosis caused by *Fusarium semitectum* has been recorded at Bahunipati and Barghat; in the latter place it occurred on trees where the plastic bags were not removed before planting. It has caused serious damage in India (S. Singh *et al.*, 1983).

Varieties and cultivars

With the arrival of the psyllid the most important aspect of different varieties is their resistance to or tolerance of psyllid attack. Unfortunately some of the varieties which up to the present have produced the highest yields (K 8, K 28, K 67) are very susceptible to psyllid. At Adabhar the hybrid *L. leucocephala* x *L. diversifolia*, K 743, had at the age of 42 months a cumulative yield from thinnings (half the crop pollarded at 19 months, the other half at 42 months) of 10 t ha⁻¹ yr⁻¹ oven-dry wood biomass, but became heavily infested by the

psyllid, as was the Sunsari land race included in the same trial (Neil, 1990i). A hybrid of these two species, provenance unstated, also did very well at Lampatan, near Pokhara (900 m); it provided the highest yields of fodder from lopping of all the *Leucaena* provenances included in this trial, but this was before the psyllid reached the area (Veldhuis, 1988a).

K 636 had the best height growth in a trial at Adabhar (6.0 m in 22 months) and up to 1989 had suffered no damage from psyllid in Nepal, according to L. Joshi, although it is susceptible in other countries. It tends to be a rather tall, slender tree with less volume production in relation to height than some other varieties; for instance at Sagarnath at 3.5 years old it had the second best height growth (6.2 m), but only 55 per cent of the volume growth of the best variety. K 156, *L. diversifolia*, was second best in height growth at Adabhar (5.9 m in 22 months), but again is of relatively low volume production. At Sagarnath the mean weight of wood per tree was slightly less than 50 per cent of that from the best variety, a local land race from Tarahara. It has been found to be fairly resistant to psyllid in Taiwan and elsewhere.

Among highly resistant species and varieties according to L. Joshi are *L. collinsii*, K 740, and *L. esculenta*, K 897; also *L. pallida*, K 376, and *L. retusa*, though growth of the last was poor. The hybrid KX 3 planted at 1300 m had only one adult psyllid. Other resistant hybrids, KX 1 (*L. pallida* x *L. diversifolia*), and KX 2 (*L. pallida* x *L. leucocephala*) are promising. In addition to K 156, the variety K 145 of *L. diversifolia* is also promising. Most of these varieties are under trial in the World Neighbours' project at Bahunipati at about 1000 m. Another aspect needing investigation is to find varieties capable of growing above 1000 m, where in general *L. leucocephala* does badly.

Rate of growth

Rates of growth from past trials are of little relevance at present until the effect of the psyllid on growth is clearer. Although in the constantly humid tropics very high growth rates, with mean annual increments of 30–40 m³ ha⁻¹, have been recorded these are unlikely to be reached in Nepal, where 20 m³ ha⁻¹ would be a more likely figure, provided the psyllid problem is solved.

Uses

Leucaena is a multipurpose tree, producing fodder, fuelwood and small timber, and improving the soil. The fodder is highly nutritive and is comparable to lucerne. Its content of crude protein ranges from 15 to 21 per cent, with a digestibility factor of 50 to 70 per cent, and between 55 and 70 per cent digestible nutrients. The main disadvantage of *Leucaena* as a fodder is that it contains mimosine which is toxic, especially to non-ruminant animals such as

horses, pigs and poultry; for this type of animal *Leucaena* leaves should not form more than five per cent of their diet. Ruminants (cattle, sheep, buffaloes), are different in that they can degrade mimosine to another substance, DHP (3-hydroxy-4 (1H) pyridone), in their digestive system. Unfortunately DHP tends to cause goitre and other disturbances. However, in some parts of the world ruminants have bacteria in their digestive systems which can degrade DHP and remove this danger, and such animals can thrive on diets containing a high proportion of *Leucaena* leaves. It has been found that if a few animals which have these bacteria are introduced among others which do not have them, the whole herd very rapidly obtains the bacteria and symptoms of *Leucaena* toxicity disappear. This is a simple method of overcoming the problem of *Leucaena* toxicity in ruminants (R.J. Jones and Bray, 1983; Lowry, 1983). Dry matter yields of fodder can be as high as 20 t ha⁻¹ yr⁻¹, but in the dry tropics 8 t ha⁻¹ yr⁻¹ would be a good yield.

Leucaena produces a good fuelwood, with a weight of about 540 kg m⁻³ and a calorific value of 17,600 to 19,300 kJ kg⁻¹. It also makes a good charcoal. The wood can be used for poles, and has potential for sawn timber and paper pulp.

The tree fixes large quantities of nitrogen and hence is a soil improver. It has been used as a shade and nurse tree for coffee and tea, and has been suggested for use as a green firebreak. It has also been used in alley cropping, where hedges of *Leucaena* are planted between agricultural crops, and the loppings from the hedges used as a green manure.

Importance in Nepal

The potential value of *Leucaena* in Nepal cannot be evaluated until the effects of the psyllid are clearer. If, as has happened in some countries, one or two years after the first arrival of the psyllid the severity of the attack diminishes, it is possible that in Nepal the eventual level of infestation could be tolerated. There are also the possibilities of finding resistant varieties, and biological control.

At Bahunipati, Sindhupalchok District, at between 900 and 1000 m, the World Neighbours organization had been very successful in persuading farmers to grow *Leucaena* along their terrace risers. The trees were planted in June at 1 m spacing, in pits with compost, and in six months had grown beyond the reach of the livestock that were allowed into the fields at that time to graze the stubble; during the next monsoon and thereafter lopping for fodder was possible every 2–4 weeks. Contour hedges from direct sown *Leucaena* were also established in farmers' fields. The use of *Leucaena* had been widely accepted by local farmers, who up to 1988 had planted nearly 59,000 trees. The main variety used was K 8 (Arens, 1984; Baidya, 1990). Unfortunately the area

has become severely affected by psyllid, and the whole scheme is having to be re-thought.

References: There is a large literature on *Leucaena*. A bibliography has been published (Oakes, 1982) and there is an annual publication, *Leucaena Research Reports*, which has been appearing since 1979. The National Academy of Sciences (1977) has published a monograph. Other references: Baidya (1990); Brewbacker (1983); M.W. Campbell (1983a); Hawkins (1983); IDRC (1983); Lamichhaney and Joshi (1980); National Academy of Sciences (1979; 1980); Napier (1987c); Napier and Robbins (1989); Neil (1990i); R. Shakya (1990); R.V. Singh (1982); Westwood (1987).

Leucaena diversifolia (Schlecht) Benth.

This species grows naturally at higher elevations than *L. leucocephala* and has also been included in trials in Nepal. Some provenances are reputed to be psyllid-resistant. See *Leucaena leucocephala*, Varieties and cultivars, page 599.

Reference: Harrison (1988).

Leucosceptrum Sm.

Labiatae

Leucosceptrum canum Sm.

Nepali: ghurmiso.

Shrub or small tree. Branches and undersides of leaves densely clothed in white or brown wool. Leaves opposite, lanceolate, 15–30 cm long, on stalks 2.5 cm long. Flowers small, whitish, with long protruding stamens, in dense cylindrical spikes 10–15 cm long. It is found between 1000 and 2800 m, from east to west Nepal, and does not grow to more than about 10 m tall. It coppices freely (Gamble, 1922). It can be propagated by cuttings, planted *in situ*, with two pairs of buds below the surface of the soil, and one pair above it. This method gave 50 per cent success, with a height growth of 2 m in the first year (Bolle, 1983), though Neville (1984) doubts whether this rate of growth can be achieved on all sites. It can also be raised as seedlings. Neville (1985d) recorded 30,000 and 80,000 seedlings raised from 1 kg of seed in two different nurseries. Growth from seedlings may, however, be slow, especially at high altitudes. At Pangme,

Sankhuwasabha District, at about 2100 m, *L. canum* planted under pines had 100 per cent survival but was only 80 cm tall after two years (L. Joshi and Sherpa, 1992), and at Salle, Dhankuta District, over 2000 m, it had 80 per cent survivors with a mean height of only 50 cm, and a very slow rate of height increment, at the same age (Sherpa *et al.*, 1992). Gamble says that diameter increment in natural trees is equivalent to 5 cm in 3–5 years. It is said to be a good fodder for sheep and goats, and in places it is eaten by larger animals. In Salle village in Dhankuta District all farmers had some trees on their land, the average number being 15 (B. Thapa *et al.*, 1990), but is not included in the lists of fodder trees for Lamjung District (K.P. Gajurel *et al.*, 1987), Bara and Dhading Districts (Upadhyay, 1991), Dolakha District (Robinson and Neupane, 1988) or Lalitpur (Upton, 1990). Its wood weighs about 630 kg m⁻³, and is a fair fuel (Gamble, 1922). The tree has been used for roadside slope protection along the Lamosangu-Jiri road.

Lithocarpus species see under *Quercus*.

Litsea Lam.

Lauraceae

Trees and shrubs. Leaves alternate, pinnately veined. Flowers small, in 4–6 flowered heads, enclosed by large concave bracts in bud; male and female on different trees. Perianth in six parts. Stamens 12, anthers four-celled. Fruit borne on a cup formed from the persistent perianth.

Litsea cubeba (Lour.) Pers.

(Syn. *L. citrata* Blume)

Nepali: siltimur

Evergreen. Leaves aromatic when crushed, lanceolate, 7–14 cm by 2–4 cm, tapering to a long point. Heads on slender stalks. Fruit 6–7 mm in diameter on thickened stalk about 4 mm long. This species occurs between 1000 and 2700 m, particularly in areas of rather heavy rainfall, on north- and northwest-facing slopes.

The seed ripens between August and September; there are about 14,000 seeds kg⁻¹. The seed is recalcitrant and should be sown as soon as possible after collection, after the flesh has been removed. It should not be allowed to dry out. An alternative is to store it in moist sand in pots or wire mesh bags in pits.

If the seed is sown after September it will not germinate until the following spring; otherwise it will germinate 4–6 weeks after sowing, and complete germination 6–8 weeks later. The germination percentage is usually high, more than 60. The seed should be sown in beds or trays, protected with wire mesh against rodents, and pricked out when 3–6 primary leaves have developed, into 7.5 cm x 10 cm lay-flat polypots, containing a mixture of soil with 20–25 per cent compost. Sowing directly into polypots is less satisfactory. The seedlings need protection against heavy rain. At lower altitudes they will need 11–14 months in the nursery, before the monsoon, when they should be 20–30 cm tall with a root-collar diameter of more than 2.5 mm, and a moderately well-developed taproot. At higher altitudes an extra year in the nursery may be needed. Attempts to propagate *L. cubeba* by stem cuttings from one-year-old plants, at Chalnakhel, resulted in only five per cent rooting (Napier, 1988).

It is relatively fast growing when young. At Chalnakhel (1370 m) in a cultivated, weeded and fertilized plot it reached 2.6 m in height at 18 months old, being the second fastest growing species in this trial. At Kadambas (1450 m) it was 1.8 m tall after 40 months, and the fastest growing species. At high altitudes it is damaged by frost; for instance at Salle, Dhankuta District (2000 m) it averaged only 43 cm in height after two years, and the leading shoots had frost damage.

On exposed high altitude sites it benefits from the shelter of pines. At Tistung (1900 m) unfertilized plants in the open had only six per cent survivors, whereas under the shade of pines there were 93 per cent. However here addition of half a *pathi* (2.2 l) of compost per tree increased survival in the open from six per cent to 93 per cent; under shade survival was slightly poorer with compost, but mean height increased from 44 to 58 cm, after 18 months. Addition of Complexol, a 20:20:0 mineral fertilizer, has produced contradictory results; it increased height by 18 per cent at Irkhu, but reduced it by 46 per cent at Melechaur, both under pine shade.

It is of only moderate value for fodder, and in the hills above Pokhara it is not used for this purpose, but only for fuel. The wood weighs about 580 kg m⁻³. The fruits are valued as a spice for adding to fruit, and as a cure for stomach disorders. An oil is extracted from bark, leaves and fruits. About 20 t are collected annually, mainly from the hills near Pokhara (Natural Products Institute, n.d., Bulletin 24).

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhaney and Joshi (1980); Napier and Robbins (1989).

***Litsea monopetala* (Roxb.) Pers.**

(Syn. *L. polyantha* Juss.)

Nepali: kutmero, (kutmiro, kadmero), ratmati, ris, putmero, (patmaro).

Evergreen. Leaves broadly elliptic, 9–24 cm by 5–11 cm, apex blunt or with a small point. Flowers densely hairy, in dense clusters. Fruit about 7 mm long, borne on a cup, on slender stalk 9–12 mm long.

Natural occurrence

From the Terai to 1450 m, in *Shorea robusta* forest and tropical evergreen forest. Outside Nepal its range extends from Kumaon to Sikkim, Bangladesh, Burma and southwest China.

Silvicultural characteristics

A medium-sized tree. It does best on loamy soil, but has succeeded on gentle slopes facing southwest, with stony impoverished soil (Schaltenbrand, 1982). It can tolerate light frost.

Artificial regeneration

The seed ripens between late May and early August, according to the locality; there are about 5300 seeds kg⁻¹. It is recalcitrant, losing its viability very rapidly, and should be sown as soon as possible after collection, after removal of the flesh. The fruit is black when ripe, but slightly unripe fruit also contain viable seeds; the green fruit may be left for a day or two to turn black, and then the seed can be removed (Kessler, 1981).

Germination of fresh seed is usually fairly good, up to 62 per cent. Germination usually begins two weeks after sowing, and is complete within two weeks. The seed can be sown directly into pots, in holes made the size of the seed, and covered by 3–4 mm of soil. An alternative, especially where rodents are a problem, is to sow the seed in beds or trays protected by wire mesh, and to prick the seedlings out into polypots when they have 2–4 primary leaves: 7.5 cm x 10 cm lay-flat pots should be used, with a good potting mixture containing 20–25 per cent compost. The seedlings should be shaded for 2–4 weeks after pricking out; otherwise shade is unnecessary except for protection against heavy rain, and in winter at night, if there is a danger of frost.

Owing to the short viability of the seed the seedlings must remain 11–14 months in the nursery, by which time they should have reached a height of between 20–35 cm, and a root-collar diameter of more than 3.5 mm. Wildlings have been used successfully in Dolakha District.

Rate of growth

In most trials growth of young trees has been relatively slow. At Chalnakhel (1370 m) in a cultivated, weeded and fertilized trial, heights averaged only 40 cm after 18 months, compared with 2.6 m for *L. cubeba* (Napier and Parajuli, 1987). These results at Chalnakhel are, unusually, poorer than those from other trials, where between 60 and 80 cm have been recorded for this age, while near Pokhara (900 m) mean heights were 1.1 m at 17 months and 1.8 m at 34 months (van der Dool, 1987). Y.B. Malla (1988) measured trees planted by farmers in the Pakhribas area. He obtained the following results (Table 47). Between two and four trees were measured in each class. Some farmers weeded, mulched and manured their trees. In India trees in natural forest had mean annual diameter increments of between 0.8 and 2.5 cm.

Table 47—Rate of growth of *Litsea monopetala*

Age (yr)	Height (m)	dbh (cm)
1	0.6	—
2	1.4	—
3	2.7	4.1
4	2.5	4.0
5	3.7	4.7
6	4.1	5.1
7	4.4	6.9
8	4.7	7.3

Uses

In many parts of Nepal it is one of the most important fodder trees. The leaves contain 14–17 per cent crude protein, though its digestibility is only about 12 per cent. The metabolizable energy content is high. The tannin content is moderate, reaching a peak in February and March (Wood *et al.*, 1992). Buffaloes allowed to feed on it ad lib, in addition to their normal ration, ate an average of 8.5 kg per day, and increased their milk yields by an average of 0.25 kg per day as a result (N.P. Shrestha and Pakhrin, 1988). Some farmers in Dhading District, however, said there were health hazards if it was fed during the time of new flushing of the leaves during the pre-monsoon period (Upadhyay, 1991).

Fodder yields in Lamjung District were estimated to average 125 kg green weight of fodder per tree annually (K.P. Gajurel *et al.*, 1987). Against this T.J. Wormald *et al.* (1983) estimated annual dry leaf yield at 3 kg from trees 20 cm in diameter, 19 kg from those 30 cm in diameter, and 25 kg from those 40 cm in diameter. In Dhading District it was the most used species obtained from farmland (Upadhyay, 1991). Farmers valued it for its fast growth, high production of foliage, relatively light competition with agricultural crops, and to a lesser extent for its nutritional value. At Ratnapuri at the foot of the Siwaliks it was of minor importance; there it was lopped mainly in the post-monsoon period, but with some use at other periods of the year. In Sunderbazar, Lamjung District, it formed 9.5 per cent of the fodder trees in the village studied, and produced about nine per cent of the tree fodder consumed. The main lopping period was between mid-March and mid-May (K.P. Gajurel *et al.*, 1987). In Rahi, Pokhara Forestry Division, it formed nearly nine per cent of the fodder trees on farmers' land; there it was lopped between September and February (Hawkins and Malla, 1983). In Dolakha District it formed three per cent of the stock of fodder trees, but was fourth in popularity among farmers, and the second most popular tree to be planted by them (Robinson and Neupane, 1988). In Lalitpur District it is mainly important between 650 and 1250 m; in February 80 per cent of farmers there were lopping it, and there was also a good deal cut in November–December, and slightly less in April (Upton, 1990). In the same district it was being planted by farmers, though on a rather small scale and with moderate to poor survival rates (Hausler, 1990). It is also an important fodder at Lumle and Pakhribas, and generally in its main range of occurrence, between 500 and 1500 m. The wood is used for agricultural implements; it weighs about 610 kg m⁻³.

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhane and Joshi (1980); Mader and Stewart (1983); Napier and Robbins (1989); Panday (1976a; 1979; 1982).

Note: There are ten more species of *Litsea* in Nepal.

Melia L.

Meliaceae

Melia azadirachta see *Azadirachta indica*

***Melia azedarach* L.**

Nepali: bakeno (bakaino).

Persian lilac.

Deciduous tree. Leaves alternate, bi-, occasionally tripinnate; leaflets usually serrate. Flowers lilac, pink or white, with a tube at the centre on which the stamens stand. Fruit a drupe, up to 4 cm in diameter.

There are a number of forms, some of which have been distinguished as different species. Following Mabberley (1984) two main forms may be distinguished, the wild form and the Indian cultivar. The wild form is a tall tree up to 40 m tall, with more or less entire leaflets, which are dark above, and paler below, and when young are densely covered in stellate hairs. The petals are white or pale mauve, often pubescent inside, and the staminal tube cream or pale mauve, darkening to purple as it gets old. This is sometimes called *Melia dubia* Cav. or *M. composita* Willd. The Indian cultivar is a smaller tree. The leaflets are always serrately toothed, and are pale green and almost without hairs. The petals are mauve, pink, blue or occasionally white, and the staminal tube is purple. Intermediates with the wild form occur.

Occurrence

The wild form grows between 700 and 1300 m, usually in rather moist forests, or in valleys in *Schima-Castanopsis* forest. It extends eastwards to Burma and Thailand. The cultivated form may not be indigenous to Nepal; it is native to Iran (hence its English name, Persian lilac), and probably Baluchistan and Kashmir, and is a tree of rather arid climates.

Silvicultural characteristics

The account which follows is general. There are probably differences between the wild and cultivated forms, but these are often not distinguished in the literature. Light-demanding, deciduous trees. The seedlings have some resistance to frost, but are killed by severe frost; the wild form is less frost-resistant than the cultivated form. The trees will survive on shallow soils, but their rate of growth is strongly influenced by soil depth and fertility, and the very rapid growth of which they are capable is only achieved on deep, well-drained and reasonably fertile soils. Even quite large trees may be killed by moderate fires, though they will usually shoot from the base after having been burnt. They are liable to damage from strong winds, both by being uprooted, and by the stems being broken. Seedlings are liable to damage by browsing. *Melia azedarach* coppices well, and even fairly small seedlings will shoot from the base after the stem has been cut. The seedling soon develops a strong taproot.

Artificial regeneration

The seed ripens between November and March; the ripe fruits remain on the trees for a long time, sometimes until the rains begin, so the possible period for collecting seeds is a long one. The fruit is yellow at first and smooth, but it becomes wrinkled as it gets older. It contains a single very hard stone in which there are usually five seeds. There are about 850 dried fruit, or 1200–1500 cleaned stones kg^{-1} .

Extraction of the seed from the hard stone is laborious, as the stones have to be broken by hammers and the seed picked out carefully. Thus the usual practice is to sow the stone whole; however in Thailand the seed is extracted, as this gives quicker germination. The whole stones, after the pulp has been removed from them, can be stored for several years in sealed containers without serious loss of viability. Troup (1921) reports that in one case seed (stones) stored for a year had four times the fertility of fresh seed.

Germination of the stones after they have been sown is often very slow; indeed there seems to be a tendency for seed not to germinate until March or April, irrespective of the date of sowing or the altitude of the nursery. J. Stewart (1983b) reports that in Doti District seed sown in May will germinate in 2–3 weeks, but earlier sown seed takes 6–8 weeks. Seed sown in November or December may take up to four months to germinate. Germination can be speeded up by cracking the stones with a hammer before they are sown. Other techniques suggested are soaking the stones in water for several days, or keeping them in liquid farmyard manure for about a week, but it is not known how effective these methods are.

Eventual germination rates are usually fairly good, and the median number of plants raised from 1 kg of stones is about 1200. As several seedlings are produced from each stone, sowing directly into polypots is undesirable; the stones should rather be sown in lines 8–10 cm apart in beds, with the stones 5 cm apart in the lines. The seedlings are pricked out into 10 cm x 18 cm lay-flat polythene pots a few days after germination. Some care is needed in pricking out as the seedlings grow in small clumps from each stone, and their roots tend to be entangled. Shade is necessary for about a week after pricking out.

In nurseries below 1500 m, 3–4 months will be needed to produce plantable seedlings by the monsoon; indeed J. Stewart (1983b) reports that seedlings of plantable size in July can be raised from seed sown in May, in warm localities. Above 1500 m the seed should be sown in August. Regular root pruning is essential. It is not desirable to keep *M. azedarach* seedlings in the nursery for more than a year; however if this is unavoidable the shoots should be pruned to about 10 cm between April and June, and root pruning continued during the whole of the active growing season.

Melia azedarach can also be propagated from stumps. Seed sown in the rains of one year will produce plantable stumps by the next monsoon. Trials of bare-root planting have generally given poor results. In plantations *M. azedarach* needs to be well weeded if good growth is to be obtained, and it should be kept free from overhead shade. In the Terai taungya has been used successfully.

Provenances

In reports of trials the provenance used is rarely stated, but in view of the ecological differences between the wild and cultivated forms there are likely to be big differences in their performance in plantations, and adaptation to different conditions. Recently a South American variety, Gigante, has been introduced into the Terai. It grows faster than other varieties and has straighter stems (Anon., 1990b).

Rate of growth

On good sites growth is rapid. In Thailand, on a deep red loam, at 1000 m, and with about 1500 mm annual rainfall, trees (of the wild form) reached 3 m in height within a year. There, a mean annual diameter increment of 1.3–1.7 cm may be expected in early life, though later the growth rate slows down. In Nepal the best rate of growth recorded was 4.5 m in 13 months, with 90 per cent survival, under taungya in Dang District, in the inner Terai (Demanski and Bashyal, 1990). At Butwal (100 m) trees 30 months old had 100 per cent survival with a mean height of 4.5 m and a mean dbh of 2.6 cm. This rate of growth was however exceeded by a number of other species including *Acrocarpus*, *Eucalyptus camaldulensis*, and *Dalbergia sissoo* (Neil, 1990e). At higher altitudes recorded growth is much slower, usually not more than 1 m in 30 months at altitudes around 1400 m. Over about 1800 m, *M. azedarach* has usually failed.

Uses

According to R.V. Singh (1982) the leaves are highly nutritious; the crude protein content is about 12 per cent (D. Bajracharya *et al.*, 1985). However *M. azedarach* is little used as a fodder tree in Nepal and when used it is almost exclusively as fodder for sheep and goats, not cattle (Panday, 1982). The timber is decorative and used for furniture. It is rather light in weight (400–600 kg m⁻³), and has an energy content of 20,900 kJ kg⁻¹ (heartwood), 21,300 kJ kg⁻¹ (sapwood) (Hawkins, 1982); it can be considered as a medium-quality fuel. Bark, flowers, and fruits contain a bitter narcotic material, which is used in medicine, but may also poison animals if they eat the fruit (Storrs and Storrs, 1984).

Importance in Nepal

Melia azedarach has been raised on a large scale in community forestry nurseries in Nepal, largely because its seed is easy to collect and it can be raised in nurseries in a short time. It is not, however, a popular species among the local people, nor has its general survival rate in plantations been very promising, with a few exceptions (see below). Its potential value is as a producer of high volumes of moderately good fuelwood, and as a fast-growing utility timber tree, but these potentialities will only be realized if the tree is planted on sites with deep fertile soil. On poorer sites other species are preferable. Survival in the Community Forestry Project's 1981 and 1982 plantations was 55 per cent; in the 1983 plantations, 37 per cent. Of trees planted by individual farmers in 1981 and 1982, 48 per cent survived, and similar figures were recorded in 1983 (J.G. Campbell and Bhattarai, 1983a; Community Forestry Development Project, 1984). In the KHARDEP area 60 per cent of trees planted by farmers survived (N.C.G. Hopkins, 1984). However, 86 per cent survival was obtained in Pokhara in 1980 (Grob, 1982), and in Tanahun at 800–1000 m performance was reported to be good (van Ginkel, 1984). The generally poor survival may be due to faulty techniques in some places (plants too small, root pruning neglected), or to plantation on unsuitable sites. However other species have survived better, and there is no reason to suppose that better techniques were used in raising and planting these other species.

F. Thapa *et al.* (1991b) estimated that a farmer in the Terai could obtain the fuelwood needs of his family (10 t air-dry weight per year) from 1670 *M. azedarach* trees on a one-year rotation. If planted at 1 m x 50 cm this would need 835 m² of land.

References: M.W. Campbell (1983a); Forest Research Institute (1963); Ghosh (1977); H.B. Joshi (1980); Lamichhane and Joshi (1980); Mader and Stewart (1983); Magini and Tulstrup (1955); Napier and Robbins (1989); National Academy of Sciences (1983b); R.V. Singh (1982); Stewart (1983); Streets (1962); Troup (1921).

Melia indica see *Azadirachta indica*.

Michelia L.

Magnoliaceae

Nepali: champ.

Trees. Leaves with vertical scar on leafstalk. Flowers on short stalks in leaf axils. Carpels in fruit spread out along the axis, in a loose spiral, quite separate from each other.

Key to species

(1) Twigs, leaf stalks and undersides of leaves covered with dense soft greyish-white hairs; flowers 5–8 cm in diameter
..... *M. velutina* DC. (Nepali: gogai champ, suna champ, phusre champ)

(1) Twigs and leaves soon becoming hairless or nearly so; hairs on undersides of leaves confined to veins 2

(2) Scar on leaf stalk less than half as long as stalk; leaves usually more than three times as long as broad; hairs if present reddish; flower buds large, densely covered in orange brown hairs; flowers white, 10–15 cm across
..... *M. doltso* Buch.-Ham. ex DC. (Nepali: rani champ)

(2) Scar on leaf stalk more than half as long as stalk; leaves less than 2.5 times as long as broad; hairs if present greyish; flowers less than 8 cm across, usually yellowish 3

(3) Leaves widest below middle; apex usually prolonged into long point; secondary veins thicker than tertiary; flowers yellow turning orange
..... *M. champaca*

(3) Leaves widest near middle; point at apex short and blunt, or apex rounded; secondary veins scarcely thicker than tertiary; flowers pale yellow
..... *M. kisopa* Buch.-Ham. ex DC. (Nepali: seto champ, ban champ)

As all species are called champ in Nepali there is a possibility that some records of *M. champaca* may refer to other species. *Michelia champaca* is rather rare in the Kathmandu Valley where the commonest species is *M. kisopa*, with an altitude range of 1300–2100 m. *Michelia doltso* tends to be at higher altitudes, above 1900 m, though there are some records from lower altitudes. *Michelia velutina* is commonest east of the Tamur Valley.

***Michelia champaca* L.**

Nepali: champ, suna champ, aule champ, phul champ.

Natural occurrence

It grows in Nepal between 450 and 1500 m, and tends to favour areas of higher rainfall, such as east of the Arun River, and the Pokhara area. It is a characteristic species of the evergreen forest of the Bhabar Terai and the lower foothills of the Siwaliks in eastern Nepal, and of some of the moister types of *Shorea robusta* forest; it is also found in the *Schima-Castanopsis* zone, again usually on moister sites. Its western limit is near the Kali Gandaki River. It is not found in the Himalaya west of Nepal, though it occurs on the Western Ghats in peninsular India. In the east its range extends to Vietnam. It is often cultivated as an ornamental tree.

Silvicultural characteristics

It is a very large evergreen tree with a straight cylindrical bole, and sheds its lower branches easily. It is a moderate light-demander, but the seedlings and saplings will grow under high shade, and in India it is used for underplanting other species. For good growth it needs a moist, well-drained, deep, fertile soil. It has some resistance to frost, but seedlings are sometimes killed by it. Young seedlings are liable to be damaged by browsing. *Michelia champaca* is rather sensitive to fire, and severe fires may kill the trees outright. However, plantations will survive light annual fires. It coppices well, and fire-damaged trees will often shoot from the base. Sudden exposure to the sun may cause the crowns to die and numerous epicormic branches to be formed.

Natural regeneration

It flowers and produces viable seeds at a relatively early age. Although it seeds almost every year much of the seed is destroyed by birds and rodents. It sometimes comes in as an understorey to moist *Shorea robusta* forest.

Artificial regeneration**Seed**

The seed ripens between August and mid-November in different localities; this can be seen when the capsules begin to open and reveal the seeds. The fruit should be collected by climbing the trees, as the seeds in fallen fruits are usually attacked by insects. There are 14,000–17,000 seeds kg⁻¹. The seed is extracted by keeping the capsules in the sun until they are nearly open, and then putting the seed in water and rubbing it together with coarse sand to remove the fleshy red or pink aril which surrounds it. This aril contains a powerful germination

inhibitor, and if it is not removed the seeds will not germinate (Robbins, 1988a). Seeds which float in water are infertile and should be thrown away.

Storage of the seed has been investigated by Robbins. He found that seed stored without removing the aril did not germinate. In seed with the aril removed, dried to 11 per cent moisture content, and stored in sealed polythene bags at 5°C, the original germination percentage of 86 dropped to 50 by three months and to nil by nine months. Seed stored in moist sand at 5°C retained its viability well for at least nine months. In India partially dried seed (21 per cent moisture content) stored in sealed containers at room temperature was all dead within two months (Bahuguna *et al.*, 1987a). In practice the seed if mixed with damp sand, wrapped in wire gauze to prevent rodent damage, and buried 90 cm deep, can be stored for about four months without losing much viability. This is the most practicable method where refrigeration is not possible.

Nursery and plantation techniques

Seed sown in September, or in March after storing in pits, will begin to germinate 4–5 weeks after sowing. Stored seed sown later in the year will not germinate until the following spring. Two months may be needed before most of the seed germinates. Plant percentages in Nepal nurseries of 60–70 have been recorded, but 20–30 per cent is more usual. As germination tends to be irregular and rather protracted the seed should be sown in beds or trays, rather than directly into polypots. As the seed germinates, the seedlings should be pricked out, when they are still in the cotyledon stage. Thus it may be necessary to prick out on several occasions from the same seed bed. Polypots 10 cm x 18 cm lay-flat should be used, with a good potting mixture containing 20–25 per cent compost. The seedlings should be shaded until the primary leaves appear.

Below about 1000 m if seed is sown soon after collection in September to November, and germinates quickly, plantable seedlings will be ready by the next monsoon. At or above 1500 m an extra year in the nursery will be needed. At intermediate altitudes there may be difficulties, especially with seed that does not germinate before March or April; this will usually produce plants too small for planting in the next monsoon, but which may be too large if kept another year. To some extent their growth may be controlled by spacing and root pruning, or reducing watering. In India stumps from two-year-old plants have given good results in plantations, except that each stump produces numerous shoots which have to be pruned.

Because of the dangers from the champ bug (see below, Pests), in India it is usual to plant *M. champaca* in mixture with other species, or as an understorey to other fast-growing species, such as *Chukrasia tabularis*.

Pests

The most important pest of *M. champaca* is the champ bug, *Urostylis punctigera* (Hemiptera), which has caused considerable damage in plantations in the duars of Bengal and Assam, that is in the region of relatively low altitude at the foot of the Himalaya. There are no records of this insect having become a pest in Nepal, and it may not be a problem at the higher altitudes at which *M. champaca* is usually planted in this country. The nymphs and adult bugs suck the sap from the leaves and young shoots; in older trees they may kill the crowns and branches up to a diameter of about 7.5 cm, while one-year-old plants may be killed completely within two weeks. Infections may be controlled by spraying the early stage nymphs when they cluster on the young leaves and buds at the ends of the branches, and later stage nymphs when they have migrated to the bark of stems and branches.

Performance in plantations and rate of growth

Michelia champaca has generally survived well in trials, even at altitudes of 2000 m or more, though initial growth rates are sometimes slow; about 50 cm after two years on average. Data from some older trials in Parbat District, Mid-Western Development Region (R.K. Shrestha and Gautam, 1991) included 79 per cent survival and a mean height of 1.9 m at five years old, and 75 per cent survival and a mean height of 5 m at seven years old, both at an altitude of 1800 m, on a gentle to moderate slope.

These rates are slower than those recorded from India where average rates of growth from sample plot data in West Bengal are 2.4 m in height at two years, and 8.0 m in height by 8.6 cm dbh at five years, while a mean annual increment of more than 18 m³ ha⁻¹ at eight years old can be expected (Forestry Research Institute, 1975). This is perhaps due to the moister and less harsh climate of West Bengal compared with much of Nepal. Volume tables are included in E. R. Sharma and Pukkala (1990b).

Uses

It is a fodder species, though of relatively minor importance, and fodder supplies come from the forest rather than farmers' land. The timber is valuable. The heartwood is a light yellowish to olive brown and is widely used for furniture, doors and windows, and general carpentry and construction. The timber at 12 per cent moisture content weighs 460–660 kg m⁻³, and has a calorific value of 21,300 kJ kg⁻¹ (heartwood). It is easy to saw and polishes well but is not durable. In India the flowers are distilled to produce a perfume; they are also used in religious ceremonies. Various parts of the tree have medicinal uses.

Importance in Nepal

It was at one time a popular species with the local people, both for community plantations and private plantings, especially in the east, and in the region around Pokhara. However, survival in plantations has not been good; in 1981 and 1982 plantations of the Community Forestry Development Project it was only 42 per cent (J.G. Campbell and Bhattarai, 1983a). Results from private plantings have been better, 77 per cent in 1983 (Community Forestry Development Project, 1984). *Michelia champaca* is a demanding species and plantations should be confined to areas of good soil in rather moist localities. Given these conditions it could be a useful timber tree, though so far the fast growth rates obtained in India have not been reached here.

References: M.W. Campbell (1983a); Choudhury and Ghosh (1958); Forestry Research Institute (1975); Gamble (1922); Ghosh (1977); Indian Timbers (1976); Lamichhaney and Joshi (1980); Letourneux (1957); Mader and Stewart (1983); Napier and Robbins (1989); Streets (1962); Troup (1921).

Moringa Adanson

Moringaceae

Moringa oleifera Lam.

(Syn. *M. pterygosperma* Gaertn.)

Nepali: sahijan, shobhanjan.

Small soft-wooded tree. Leaves alternate, usually tripinnate, with numerous rounded leaflets 1–2 cm by 0.5–1.5 cm. Flowers white, in erect panicles. Fruit a pendent pod-like capsule, up to 30 cm long, roughly triangular in section. It originates in northwest India, but is widely cultivated in gardens in tropical countries, including the Nepalese Terai where it is often grown as a hedge plant. It is very tolerant to soil conditions, coppices and pollards well, and withstands a great deal of mechanical injury. The pods ripen between March and June, and each contains about 20 seeds. There are 3000–6000 seeds kg⁻¹. The seed does not retain its viability very well, and should be sown within a month of collection. Germination takes 9–42 days. It can also easily be raised from cuttings, from twig size to large truncheons, and this is preferable as growth is faster and selected varieties can be propagated. In recent years considerable interest has been aroused in the use of the powdered seed to clarify water; it is said to eliminate 98–99 per cent of bacteria. The fruit is eaten as a

vegetable, and sold in the market during March and April. All parts of the plant are said to have medicinal properties. The leaves are a good fodder; they fall in December and January and the new leaves are produced in February–March. The wood is very soft and light and is not much used.

References: Bengé (1987b); Forestry Research Institute (1975).

Morus L.

Moraceae

Nepali: kimbu.

Mulberry

Dioecious trees or shrubs. Leaves alternate, simple or three-lobed, pinnately veined but three- to five-nerved at base. Flowers in spikes in leaf axils, with four sepals; male with four stamens, female with two-branched style. Fruits juicy, the seeds enclosed in the enlarged fleshy calyx.

Key to species

- (1) Young shoots hairless; leaves ovate, long pointed, 2–15 cm by 2–15 cm; margin serrate often with sharp teeth; upper surface rough with minute warts, lower surface downy beneath soon becoming hairless; fruit dark purple, 1–2 cm long *M. australis* Poir. (*M. indica* auct. non L.)
- (1) Young shoots hairy or downy 2
- (2) Young shoots downy, soon becoming hairless; leaves ovate, apex acute or obtuse, 7–30 cm by 5–15 cm; margin with fairly fine, rounded teeth; hairless except for few hairs in axils of the veins on under surface; fruit white or pink, 2.5–5 cm long *M. alba* L.
- (2) Young shoots velvety or with long soft hairs 3
- (3) Fruit up to 12 cm long, yellowish; leaves with a long-pointed apex, 8–20 cm by 6–14 cm; margin with fine small teeth; softly hairy; eastern species *M. macroura* Miq. (*M. laevigata* Brandis)
- (3) Fruit 1.5–2.5 cm long, purple; leaves with a long-pointed apex, 5–20 cm long; margin with coarse, sharp-pointed teeth; sometimes with pale woolly hairs beneath when young; western species *M. serrata* Roxb.

Kimbu is the Nepali name for all species of *Morus*. The kimbu commonly planted as a fruit and fodder tree includes both *M. alba* and *M. australis*. These two species are very closely allied, if they are not in fact varieties of the same species, and are difficult to distinguish; they can be conveniently discussed together. *Morus alba* in the strict sense is probably a native of China while *M. australis* is probably indigenous to the Himalaya from Kumaon to Sikkim, but has also been very widely planted. It extends in Nepal up to 2400 m. *Morus serrata* Roxb. is indigenous to west and central Nepal at 1200 to 2400 m. It is often found in *Aesculus-Juglans-Acer* forest (Stainton, 1972). It is sometimes cultivated for fodder. *Morus macroura* Miq. which occurs between 1200 and 1700 m in eastern Nepal can easily be recognized by its long yellowish fruit. The account which follows refers mainly to *M. alba*/*M. australis*.

Silvicultural characteristics

Usually small deciduous trees, but can grow to fairly large dimensions on suitable sites. Shade-tolerant when young, and will regenerate under the canopy of other species; from the sapling stage onwards, however, they benefit from complete overhead light. They will survive on poor sites, and in India have been used for reclaiming ravines and other degraded land, but in such places growth tends to be poor and stunted; for good growth they need deep well-aerated loamy soils. At least some provenances are resistant to frost. Young plants are very liable to damage by browsing. The trees coppice well, up to a trunk diameter of about 30 cm, and can also be pollarded.

Artificial regeneration

Morus can be raised from cuttings or from seed. The former method is simpler, and should be used in places where good vegetative material is easily obtainable. It has the advantage that superior strains, either for fodder or fruit production, can be selected and propagated clonally. Hardwood cuttings are taken in January or February when the trees are leafless, either from mature trees or from cutting beds established in a nursery. They should be about 15 cm long, and about 8 mm in diameter. They are planted vertically in beds or plastic pots, in a mixture of soil, sand, and compost in the ratio of 1:2:1. The base should be pushed about 10 cm into the soil. The cuttings are kept under shade for 2–3 months until the roots are well formed. In low altitude nurseries cuttings taken in January–February are big enough to plant out by the monsoon rains; at higher altitudes another year in the nursery may be needed. In India cuttings are planted directly in the field, during the rains, without being previously rooted in the nursery. If this technique is used the cuttings should be planted vertically

with only the top 5 cm left above the soil level. Farmers sometimes use large branch cuttings (truncheons) about 1.5 m long.

For raising trees from seed, the fruit should be collected when it ripens between April and July. As all fruits on the same tree do not ripen simultaneously care should be taken to collect only ripe fruits. The pulp is rubbed off the seed which is then washed in water and dried in the sun for a few days. There are about 450,000 seeds kg^{-1} , and 43 kg of fruit will yield 1 kg of seed. The seed can be stored for up to five years if put in sealed containers after being well dried; according to M.W. Campbell (1983a) three-year-old seed has a higher percentage germination (60 per cent) than fresh seed (10 per cent). It should be sown in trays or beds, and kept under shade. Germination begins after 4–5 days, and is completed in about four weeks. It is reported that stratification in moist sand at 5°C for 30–90 days improves germination, as does soaking in water for about a week. The sowing rate should be about 3.5 g m^{-2} of bed, and the techniques for small seeded species should be used. Growth in the nursery is rapid, and for the production of seedlings in normal-sized polypots 3–4 months should be enough in low altitude nurseries. This may require the use of stored seed.

Stumps also give good results. The seedlings should be transplanted into nursery beds at a spacing of about 20 cm x 20 cm, and left until the plants are 1–2 cm in diameter at the root collar. This should normally be achieved in about a year in the nursery. For techniques for raising *M. macroura* see Ghosh (1977).

Provenances

Morus alba and *M. australis* are very variable species which grow under a wide range of climatic conditions; hence the performance of different provenances may be expected to vary a good deal. As vegetative propagation is relatively easy there is a good opportunity for selecting superior clones. According to Dutt (1992) a local large-leaved mulberry, originally introduced to Dhankuta as food for silkworms, has shown particular promise as a fodder tree for farm animals in that district.



Rate of growth

It is one of the fastest-growing fodder trees, being outgrown only by *Ficus semicordata* in most trials. In Pokhara (900 m) it reached 2.7 m in 34 months, with 83 per cent survival (van der Dool, 1987). M.B. Karki (1988) reports heights, after two years, of 1.8 m in the Terai, 2.3 m in the inner Terai, and 1.05 m at Pokhara. At higher altitudes though early survival may be quite good, height growth is poor; for instance at Salle, in Dhankuta District (2000 m) mean

height was 32 cm after two years and height growth was very slow suggesting that the trees had stagnated.

Uses

In Nepal *Morus* species are mainly valued as fruit and fodder trees. The leaves contain about 14 per cent crude protein (Panday, 1982), or 11 per cent according to D. Bajracharya *et al.* (1985). Other authors, however, report higher figures: R. V. Singh (1982) between 15 and 28 per cent, and Khatta and Kattoch (1983) 26 per cent and 18 per cent for two localities. The latter authors consider *M. alba* to be the best fodder tree out of eleven species tested in Himachal Pradesh, India. In eastern Nepal the new flush of leaves is in mid-April to mid-June (Baisakh-Jesth) and the trees can be lopped at this time, though this reduces the winter fodder availability and tends to weaken the tree. In winter it is lopped from mid-November to mid-January (Mangsir-Paush). A well-grown tree may be expected to produce 40–50 kg of fresh leaves in a year. *Morus* leaves are also extensively used in India and elsewhere as food for silkworms; for this purpose the trees are managed on very short coppice or pollard rotations. The timber is yellow or yellowish-brown, and of good quality, being used for building, furniture and agricultural implements. It weighs between 600 and 900 kg m⁻³. The heartwood has an energy content of 20,900 kJ kg⁻¹ and the sapwood 19,500 kJ kg⁻¹ (Hawkins, 1982). The fruit is edible and sweet. There is some evidence that the leaves may produce a substance toxic to seedlings of some agricultural crops, including wheat, peas and lentils, and this may restrict the use of *Morus* in farm forestry (K. Sharma *et al.*, 1987).

Importance in Nepal

Morus trees have for many years been planted by farmers in certain parts of Nepal. However, although classified as priority species in community forestry (Tyystjarvi, 1981), they have only been raised to a very limited extent in community forestry nurseries, and their take-up by farmers has not been high. There may be some good reasons for this, but otherwise *Morus* would appear to be very useful for distribution to farmers for planting on their own land.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichaney and Joshi (1980); Kessler (1981); Napier and Robbins (1989); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

Myrica L.

Myricaceae

Myrica esculenta Buch.-Ham. ex D. Don

(Syn. *M. nagi* auct. non Thunb.)

Nepali: kaphal, kabasi.

A small evergreen tree; leaves alternate, simple, leathery, 7–15 cm by 2–3.5 cm; margin entire; underside with yellowish glands. Male and female flowers on different trees, the male in cylindrical spikes collected together in racemes, the female in globular heads collected in slender spikes. Fruit an ellipsoid drupe about 1 cm long, covered at first with brownish hairs, eventually covered with fleshy red tubercles. It is found in Nepal between 1000 and 2300 m, usually near villages and in cultivated areas, more or less throughout the country at suitable altitudes. It has been found to colonize pine plantations, the seed being probably distributed by birds. It is also a constituent of regrowth of degraded *Schima-Castanopsis* forest.

The fruit ripens between April and July. After it is collected the pulp should be removed from the seed, which is then washed and dried. There are about 8000 seeds kg⁻¹. According to M.W. Campbell (1983a) the seed has a viability of about six months, and will give 55–75 per cent germination. He recommends sowing the seed immediately after collection and pricking out the seedlings into polypots after about three months, though this appears rather a long time according to modern ideas. The seed takes about one month to germinate. The seedlings can be planted out after a year in the nursery, by which time they should be about 15 cm tall. Little information is available about its performance as a plantation tree, but Hirsbrunner (1968?) reports fair success on moist sites in degraded hill forests between 1800 and 2100 m at Ranipawa.

The fruit is edible, and a yellow dye is obtained from the bark, which is also medicinal, being astringent and used against fevers. There is a small trade in it; the Department of Medicinal Plants (1970) estimates an export of about 1000 maunds of bark (about 35 t). The wood weighs about 750 kg m⁻³.

References: M.W. Campbell (1983a); Gamble (1922); Hirsbrunner (1968?); Schaltenbrand (1982).

Paulownia Sieb. and Zucc.

Scrophulariaceae

A genus of about 17 trees, mostly from China, some of which have recently been introduced to Nepal. So far the most successful one has been *Paulownia fortunei* Hemsl., with white flowers about 10 cm long, spotted inside with purple, and fruits 5 cm by 3 cm. A provenance of this from Guizhou, China, at 26°N, in trials at Adabhar has grown to 6.6 m in height by 6.9 cm dbh, with 84 per cent survival, at the age of 30 months. This was interplanted in a *Dalbergia sissoo* plantation one year old, and the height growth was slightly better than that of the *D. sissoo*, though this was a year older. The same provenance planted on a steep stony dry south-facing slope at Kadambas (1500 m) averaged 1.5 m in height at 29 months old, though it started rather badly and the survival rate was only 67 per cent; it was the fastest-growing species in this particular trial. Another provenance, from Jiangsu, China, 32°N did less well, particularly at the Kadambas site. At Naldung, Kabhrepalanchok District (1600 m), and Nagarkot, Bhaktapur District seedlings of *P. fortunei* died back during the winter, dry season after planting; some shot again from their bases during the next monsoon, but there was more dieback during the next dry season.

Paulownia tomentosa Steud. has handsome pale violet flowers and is widely planted for ornament in Europe and North America. This generally has done less well than *P. fortunei*. At Adabhar at 30 months old, survival of a provenance from Henan, China (34°N) was only 39 per cent, with a mean height of 2.5 m, and on the south-facing slope at Kadambas only 25 per cent survived. At Lopre, Parbat District (2400 m) seedlings of *P. tomentosa* all died back after planting, and at Lumle, Naldung and Nagarkot there was also dieback, though in some cases the seedlings shot again from the bases. However even when survival was good, growth was not promising; for example at Kadambas, on a north-facing slope, survival at 28 months was 100 per cent, but the mean height only 62 cm (Neil, 1990b; R. Shakya, 1991).

The seed is small, 560,000 seeds kg⁻¹ for *P. tomentosa*. There are no special features for nursery treatment; the seed is sown in germination trays and the seedlings pricked out into polythene pots. At Chalnakhel (1370 m) 10–12 weeks are needed to provide plantable seedlings; at Hetauda (450 m) about eight weeks. At Chalnakhel seed sown before winter produced seedlings which all died back during the cold weather, but resprouted in the spring. Seed sown in the spring tends to produce tall but poorly lignified seedlings; a hardening off period is needed before such seedlings are suitable for planting. In the United States, *Paulownia* species are also propagated from root cuttings, and green-

wood cuttings, raised in a glasshouse. They can also be propagated vegetatively from the leaves, when they are unfolding and about 2.5 cm long (Bailey and Bailey, 1966).

Paulownia produces a light but strong and valuable timber used in particular for musical instruments; also for furniture and plywood. The leaves are a good fodder and green manure. So far *P. fortunei* is showing considerable promise as a fast-growing species in the Bhabar Terai. In other parts of the world, however, *Paulownia* species have been very subject to insect and fungus attack. So far this seems not to have been serious in Nepal, apart from defoliation by caterpillars and damping-off in the nursery (Rayachhetry and Karki, 1988), but caution is needed before large-scale plantations are undertaken.

Paulownia kawakamii T. Ito, from Taiwan, has also been introduced into Nepal. It differs from *P. fortunei* in its much smaller flowers (4 cm) and fruits (3 cm).

References: Beckjord (1984); Beckjord *et al.* (1984); Bengé (1987a); Neil (1990b); Rayachhetry and Karki (1988).

Phyllanthus L.

Euphorbiaceae

Phyllanthus emblica L.

(Syn. *Emblica officinalis* Gaertn.)

Nepali: amala.

Usually a small tree, found in most parts of Nepal below 1500 m, occasionally extending to higher altitudes, mainly valued for its edible fruit. The tree is a strong light-demander. The growth of young seedlings is considerably retarded by weed competition. Reports of frost-tolerance vary, but frost is unlikely to be a serious problem in most areas where *P. emblica* is planted. It coppices well and pollards moderately well. It is used in afforestation of degraded sites in the drier parts of India.

The fruit ripens in Nepal between August and February, most commonly between September and January. Each fleshy fruit contains a hard stone with 4–6 seeds. The seeds can be extracted by exposing the stones to the sun until they crack and allow the seed to escape. The seed weight appears to be rather variable, with numbers reported to range from 34,000 seeds kg⁻¹ (M.W. Campbell, 1983a) to 89,000 seeds kg⁻¹ (Ghosh, 1977). There are also conflicting reports about the viability of the seed; Troup (1921) says that it does not retain

its vitality long, but M.W. Campbell (1983a) states that it can be stored for at least 12 months. The seed is sown in beds, and later pricked out into polythene pots. Campbell recommends nine months in the nursery, implying September or October sowing, but Indian authorities state that seed sown in March will produce seedlings plantable in the subsequent rainy season.

Early growth in favourable conditions can be rapid, and Troup records a height of 5 m in four years from seed. Under natural conditions growth is considerably slower, with a mean annual diameter increment of 5–7 mm. *Phyllanthus emblica* has not been much planted in Nepal.

The fruit is made into various sorts of preserves. The fruit has also a number of medicinal uses. It is commonly sold in local markets, and there is a small export trade, estimated at 300 *maund* (about 11 t) (Department of Medicinal Plants, 1970). The bark, leaves, and fruit are used for tanning. The wood is red and hard, and is used for agricultural implements and inferior building and furniture in India; it weighs about 840 kg m⁻³ and is a good fuelwood.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichhaney and Joshi (1980); Troup (1921).

Pinus L.

Pinaceae

Nepali: *salla*

Pine.

Trees. Leaves needle-like, borne in clusters of two, three or five on short shoots, with brown membranous sheaths at base. Cones with woody scales bearing the seeds; bracts not protruding; cones falling entire, not breaking up on tree.

Two species of pine are indigenous to Nepal, *Pinus roxburghii* (chir pine, khote *salla*) mainly between 1000 and 2000 m and *P. wallichiana* (blue pine, gobre *salla*) between 1800 and 3600 m. Both species are very important in afforestation. In addition the exotic *P. patula* has been widely planted and grows considerably faster than the indigenous pines, though it is more sensitive to soil conditions. Some other species are also showing considerable promise, especially *P. maximinoi*, which has been tried at altitudes ranging from 200 to 1800 m, and which has been the fastest-growing species in almost all trials. If this promising early growth continues it could be one of the most valuable plantation species in Nepal. Other promising species are *P. greggii* at higher

altitudes, and *P. tecunumanii* (*P. oocarpa*) and some varieties of *P. caribaea* at lower altitudes.

Silvicultural characteristics

Pinus species are light-demanders, and in nature usually gregarious. Many are capable of growing on infertile soils. They are often pioneers, with broadleaved species coming in under their shade and eventually replacing them. Regeneration is best on newly exposed soil, or areas which have been burnt, and many species are adapted to periodic fires. The stems of older trees are protected by thick bark, and seedlings also may be protected in various ways, such as by a dense crown of needles which prevents fires reaching the young stems. In some species the cones remain closed until they are scorched by forest fires, after which they open and release the seeds to colonize the newly burnt areas.

Artificial regeneration

Similar methods are used for all species of *Pinus*. The seed is extracted by spreading out the cones in the sun until they are fully open, then knocking them together to shake out the seeds; this should be repeated daily until all the seed has been dislodged. The wings can be removed by putting the seed into a cloth bag and gently rubbing them together, followed by sieving them and winnowing them. Careful winnowing can remove many empty seeds. The seed should be thoroughly dried and stored in tightly sealed polythene bags or other containers, in a cool place. So treated, seed of most species will retain its viability for at least a year. For longer periods, cold storage should be used. Before the seed is sown it is often useful to put it into water in a bucket or other suitable container; those seeds which float should be discarded, as most of them will not be viable. Soaking the seed in cold water for one to two days may also shorten the time needed for germination.

If the germination percentage of the seed is known to be satisfactory, and rodents are not a problem, the simplest way of raising seedlings is to sow directly into polythene pots, at one or two seeds per pot depending on the germination capacity. Shade is rarely needed, except during very hot weather and, if used, should be removed gradually after the seedlings reach a height of about 5 cm. When germination rates are suspected to be low, or when seed is scarce (for instance imported foreign seed), and also when rodents are a problem, the seed should be sown in beds or trays and the seedlings later pricked out into polythene pots. This method is generally recommended for *P. patula*, which has an unusually light seed, most of which has to be imported. When rodents are a problem, trays or beds should be protected by wire mesh.

The sowing rate should be designed to produce 1500–3500 seedlings m⁻² of bed or trays, according to the species.

The nutrient reserves in pine seeds are enough to allow the seedlings to develop to a size suitable for pricking out, without extra nutrients from the germination medium, so a sterile seed-bed medium such as pure sand can be used. This should be a coarse sharp sand which does not form a crust on the surface after it has been watered; if facilities are available it should be sterilized before it is used. The sand should be slightly acid in reaction. This needs attention in Nepal as some river sands are strongly alkaline; for instance some samples of the sand taken from the bed of the Bagmati River near Chalnakhel were found to have a pH of 8.4 (Sharpe, 1984c). In such cases the pH of the sand may need to be amended by adding flowers of sulphur or aluminium sulphate, but it may be simpler to find other sources of sand. The surface of the sand should be quite level before the seed is sown. After sowing the seed should be covered with fine sand to a depth of between one and two times its diameter. The surface of the sand should then be firmed, by using a board. In watering, a fine spray should be used. Seed beds and trays should be shaded, unless wire mesh is used to protect the seedlings, when shade is not necessary.

The seedlings should be pricked out when they are 3–4 cm in height, when still in the cotyledon stage; they should not be allowed to grow larger. During this operation they should be held by the cotyledons, not by the stems. If the taproot is more than 3–4 cm long it should be shortened by cutting it with a sharp knife or razor blade. After the seedlings have been pricked out they may need to be kept under shade for a week or more, after which the shade should be gradually removed. In some countries the seedlings are pricked out even earlier, at the match-stick stage, when their cotyledons are still enclosed in the seed coat. They are very delicate at this stage, however, and great care is needed in handling them.

A method of raising seedlings sometimes used in research nurseries (though not, so far, in Nepal) is to pre-germinate the seeds and prick them out singly into the polythene bags as soon as the roots appear. This can be done by mixing the seed with moist sand or vermiculite and keeping it in a plastic bag under shade; once germination begins the sand and seed mixture is sieved daily, and the seeds removed and pricked out as they germinate. It is important that the sand or vermiculite should be sterile, and treatment with a fungicide is desirable. In research nurseries in Nepal a propagator is used, consisting of a timber frame over which polythene sheeting is stretched to form a miniature greenhouse. This stands on a brick or gravel base which has been sterilized by heat or formalin. The seed is sown in sterile sand in plastic trays and watered with a spray lance giving a fine mist-like spray. When most of the seed has germi-

nated the propagator is gradually opened to reduce the humidity and allow the seedlings to harden off. The propagator should be shaded when the sun is strong (Sharpe, 1984c).

The soil mixture in the polythene pots should be of a sandy loam texture, and free draining. A 3:2:1 potting mixture of forest top soil, sand and compost is suitable, but this may need to be varied according to the nature of the forest soil. Addition of pine soil to the mixture to provide mycorrhiza is essential. If mycorrhiza is deficient or absent the seedlings will remain stunted, usually in the cotyledon stage. Often mycorrhiza will begin to colonize a bed of seedlings from outside sources, perhaps spores in the soil of the nursery; when this happens small groups of healthy, vigorous green seedlings will be seen among the stunted non-mycorrhizal seedlings.

Pinus seedlings sometimes show signs of phosphate deficiency; this causes them to become stunted and of poor colour, and to remain in the primary needle stage for a long time. In nurseries where this occurs triple superphosphate should be mixed into the potting mixture at the rate of 200–300 g m⁻², equivalent to 0.2–0.3 g per seedling. If nitrogen is deficient this is best corrected by applying nitrogen fertilizers dissolved in water 2–3 months after the seed has been sown, if it is sown directly into polythene pots, or after the seedlings have been pricked out. This should not be done, however, during the cold period when the seedlings are dormant (November to February at medium altitudes). Suggested rates of application are 40 g of ammonium sulphate in 12 l of water per 1000 seedlings in standard 7.5 cm x 18 cm polythene bags. This dose may be repeated if necessary. Urea should not be used as a fertilizer for pines as it is often toxic to them. Potassium is rarely deficient in Nepal soils. These suggested rates of application are tentative, and more reliable prescriptions must await the results of trials and experience. Pine seedlings are very liable to damping-off diseases, and brown needle disease may also be a serious problem in nurseries (see below).

Root pruning is very important, and the roots should never be allowed to penetrate deeply into the nursery bed beneath the seedlings. Seedlings should be between 15 and 30 cm in height when they are planted in the field, and the dates of sowing the seed should be adjusted to produce these heights. Seedlings below 20 cm in height have been shown in trials to have lower survival rates, and the stems of small seedlings are much more likely to be bitten through by crickets. Seedlings over 30 cm in height grown in the standard 7.5 cm x 18 cm polythene pot used in Nepal will have an unsatisfactory root:shoot ratio, and there is also a great risk of root curl within the pot, which may not affect the seedlings immediately after they are planted, but may cause death several years later (Bohara and Basnet, 1983). In addition to being of the correct height the

seedlings should have a well-lignified stem at least 2 mm in diameter at the root collar, and preferably more. Seedlings which are surplus to requirements in any planting season should never be kept in the nursery for a further year, but should be destroyed.

In plantations *Pinus* species will withstand grass and weed competition better than some other species; nevertheless regular weeding will increase the rate of growth and the chances of survival. Seedlings should not be allowed to become overtopped or smothered by weed growth.

Disease and injuries

Young pine seedlings are very subject to attacks by damping-off diseases and the usual precautions should be taken against these, including growing the seedlings in an acid soil mixture, and not overwatering, not overcrowding and not overshadowing. If damping-off occurs in a nursery the seedlings should be immediately treated with fungicide. See section on Nurseries in Volume 1 of this manual for details.

A serious disease appeared during the 1980s in some nurseries raising *Pinus* species. This is brown needle disease, caused by *Mycosphaerella gibsonii*, the anamorph stage of which is known as *Cercoseptaria pini-densiflorae* (Hori and Nambu) Deighton (Ivory, 1990). The disease first appears on seedlings scattered at random through nursery beds, but then spreads until all the plants are affected. It begins on the older needles at the base of the plants, and spreads upwards to the younger needles of the leading shoots. The first symptom is the occurrence of pale green bands on the needles, which quickly turn yellow, then brown, then greyish brown, after which they die and turn greyish with lines of minute sooty spots along the needles. The disease is dispersed over short distances by raindrops splashing, during humid conditions, when abundant spores are produced from affected needles on the plant, or on recently fallen litter. Symptoms of the disease and fungal fruiting bodies appear about 40 days after the initial infection, but thereafter spores can be produced continually for several months. After the initial lag phase the build-up of infection can be very rapid in suitable conditions, such as when plants are kept in the nursery during the monsoon season.

Many species including *P. roxburghii*, *P. wallichiana*, *P. patula*, *P. caribaea* and *P. tecunumanii* can be severely blighted until they are one year old, but then the different species develop effective resistance at different rates. *Pinus patula* rapidly becomes resistant when it produces its secondary foliage, but *P. roxburghii*, *P. caribaea* and *P. tecunumanii* do so much more slowly. In *P. wallichiana* both primary and secondary foliage are very susceptible to attack

while the tree remains in its slow-growing juvenile stage, but after rapid height growth has begun the foliage is highly resistant.

The disease reduces seedling growth in the nursery, and on some occasions has resulted in deaths of many nursery plants, especially when the plants are kept for more than six months in the nursery. Many of the surviving plants are in poor health and may die after having been planted out. Certain species such as *P. roxburghii*, *P. caribaea* and *P. tecunumanii* may develop a chronic blight after having been planted out, when the more severely affected plants remain very stunted and eventually die. Considerable mortality has occurred in some trial plots from this cause. Although the disease was only confirmed in 1984, there is evidence that it had been present in Nepal for a number of years before that, and it may possibly be endemic. Thus there is no possibility at this stage of completely eradicating it. However, there are a number of measures which can be taken to reduce its spread.

Infection of newly established nurseries is probably mainly by means of infected litter in mycorrhizal soil, or by the introduction of pine seedlings from infected nurseries. To reduce the dangers of infection from mycorrhizal soil, it should be collected from local pine areas where none of the trees are less than 5 m tall. All surface vegetation should be removed by cutting and sweeping, or by burning, before the top 25 cm of soil is collected. Pine trees planted to provide a bank of mycorrhizal soil should be at least 50 m outside the nursery, and only disease-free seedlings should be used to establish them. Soil from such banks should not be used if there are any symptoms of brown needle disease on the foliage. Pine seedlings should not be transferred between nurseries.

To prevent carry-over of brown needle disease in nurseries from one season to the next, no *Pinus* trees should be planted within the nursery and all young trees should be removed from around each nursery for a distance of 50 m. *Pinus roxburghii* of all ages should, if possible, be removed from the vicinity of all nurseries. Where possible no seedlings should be kept in nurseries throughout the monsoon. In nurseries at moderate to low altitudes, where it is possible to raise seedlings in eleven months or less (sowing the seed in September to October, planting out in June–July in the next year) all old nursery stock should be removed when the planting season is over, and no seedlings allowed to remain in the nursery during the interval between planting and sowing the new stock. In high altitude nurseries, where the seedlings have to remain in the nurseries for more than a year, old and new seedlings should be separated from each other as far as possible, by at least 5 m.

The incidence of disease in the nursery can be reduced by using shade as little as possible (it should be used at most only until newly germinated seedlings are about 5 cm high, or for about 14 days after seedlings have been

pricked out). Overwatering should be avoided and where possible the seedlings should be watered in the early morning only. Fungicides can be used to prevent infection or to minimize the spread of the disease. The most effective are Benlate and Daconil, but unfortunately these are not generally available in Nepal. Some control has been achieved by using Dithane M-45 (S. Singh *et al.*, 1983b), at the rate of 100 g of Dithane and 6 ml of Triton AE spreader-sticker in 10 l of water, sprayed on by a knapsack sprayer or a watering can with a fine spray. The treatment should be repeated at weekly intervals. Infected seedlings should be removed from the nursery and burnt, and in no case used in plantations.

An orange needle rust is commonly seen on *P. roxburghii* and a similar rust has been recorded on *P. wallichiana*. The symptoms are black-brown spots on the needle which are followed by orange fruiting bodies 2–5 mm long. The rust growing on *P. roxburghii* has been identified as *Coleosporium campanulae*, which has as its alternate host species of *Campanula*, most of which in Nepal are small herbs. Thus it might be possible to reduce the incidence of the disease by eliminating *Campanula* species from nurseries and their surroundings. In general the rust does not cause great damage, but in the Tansen area, Palpa District about half of the young *Pinus* plants were severely infected, especially those growing on south-facing slopes with dry, poor soils, and about ten per cent mortality was recorded.

A stem rust caused by *Cronartium himalayense* has been seen on young *P. roxburghii* trees in Rasuwa District, and in Darchula District. Its alternative hosts are species of *Swertia* (herbs in the family Gentianaceae). So far it has not caused serious damage in Nepal, but has wiped out some exotic pines in trials in India (Cotter and Adhikari, 1987; M. Karki, 1992).

The most important insect pests of young trees are crickets and grasshoppers which bite through the stems of seedlings. This damage can be reduced by planting only well-grown seedlings with well-developed lignified stems. Pine woolly aphids causes damage to *P. roxburghii* and *P. wallichiana* of all ages. Infestation can lead to stunting, deformation, and deaths of young shoots, but more usually leads to chlorosis and death of much of the current year's needles, which are then shed. The attack rarely kills the trees but must cause some loss of increment. The presence of the pest can be confirmed by the occurrence of a white waxy material, which is mainly found around the base of needle fascicles.

Birds may cause damage in nurseries by eating the seeds or picking off the seed caps of newly germinated seedlings. The most effective way of preventing this is to cover nursery beds with wire mesh. This also reduces damage by rodents and insects such as crickets. An old method of preventing damage to

seed by birds and rodents was to coat the seed with red lead at the rate of 1 kg of red lead per 10 kg of seed. This would be worth trying.

Uses

Though pines are of no value as fodder, their fallen needles are much used as bedding for cattle, and women may often be seen collecting them for this purpose, sometimes using a special tool devised for raking together the pine needles. The wood is not preferred as a fuel, as it burns rapidly and emits much smoke. However it is still used on a wide scale, especially where other fuel is scarce, as it is in many parts of Nepal. Pines and other conifers are, of course, the main source of building timber in most of Europe and North America. In Nepal up to the present other timbers have been preferred, but this may change as supplies of hardwoods become scarcer. Pine timber has many other uses as a general utility timber for packing cases and boxes, for example, and cheap furniture. It is an excellent source for the manufacture of long-fibred paper pulp.

General references to pines: D.B. Amatya (1976); Gibson (1979); Ivory (1985); M.R. Joshi and Wyatt-Smith (1982); Napier (1984); Napier and Robbins (1989) (nursery techniques); Napier and Willan (1983); Nepal–Australia Forestry Project (1980) (trials in Nepal); S. Singh (1982); S. Singh *et al.* (1983b) (brown needle disease). Further references will be found under the individual species.

Pinus roxburghii Sarg.

(Syn. *P. longifolia* Roxb. ex Lambert)

Nepali: khote salla, aule salla, rani salla.

Chir pine.

A three-needled pine, with long needles forming spherical pompom-like clusters at the ends of the branches, especially in young trees. Cones ovoid, 10–18 cm by 6–9 cm when mature, with scales curved upwards at the apex.

Occurrence

The main area of occurrence of *P. roxburghii* in Nepal is between 900 and 1950 m, but in sheltered valleys in the foothills it sometimes extends to as low as 450 m, and in the dry upper valleys of the Karnali and Bheri it reaches 2700 m in a few localities. In the west of Nepal it forms large areas of almost pure pine forest on both north-facing and south-facing slopes, and is also found in places associated with hill *Shorea robusta* forest. In central Nepal it is largely confined

to drier areas such as south-facing slopes, and in areas of particularly heavy rainfall, such as in the hills north and east of Pokhara, it is absent altogether. In eastern Nepal it is very localized, occurring in the lower parts of the Arun and Tamur valleys, but it is absent in wetter areas even from south-facing slopes. Thus it is characteristic of sites which are either climatically or ecologically rather dry, and apparently cannot compete with other vegetation in wetter areas. Outside Nepal it extends fairly continuously as far west as Afghanistan. East of Nepal its occurrence is more sporadic; it is found in Sikkim and Bhutan, but only in drier areas.

Silvicultural characteristics

Pinus roxburghii is capable of growing to a large size, and trees over 50 m high and 1 m in diameter have been recorded from India. Although evergreen it sheds a large proportion of its needles towards the end of the dry season, from March to May. It is a strong light-demander, and the seedlings should be given full light from about three weeks after the seed has germinated. The seedlings are reasonably frost-hardy, but some protection against frost may be needed in high altitude nurseries. The tree is very tolerant of poor soil conditions and will grow even on hard, eroded red clay loams if tended properly. In some places it occurs naturally on soils derived from limestone, and so can be assumed to be able to tolerate a wide range of pH values. It does not grow well on badly drained sites.

It is a very fire-resistant species; in many parts of its range fires are a regular annual occurrence, and provided they are not too intense do little damage to mature trees. Even young trees have a considerable resistance to fire, partly because the dense almost spherical crown protects the stem from the direct action of the flames. According to Troup (1921) seedlings over one year old may be killed back to ground level by fire, but then will send up new shoots. Cattle and sheep do not graze *P. roxburghii* pine very much, but browsing by buffaloes and especially goats may do considerable damage.

Over much of its range *P. roxburghii* pine forms pure stands with practically no woody undergrowth, and often not even much grass, but with the ground covered in a carpet of dead needles. This is partially the result of fire and grazing, though Dobremez (1976) considers the almost pure *Pinus* forest to be in many places a natural climax, and not entirely dependent on fire for its formation. Pure *Pinus* plantations without undergrowth may be an erosion hazard on steep slopes, and this should be borne in mind in afforestation programmes. A light understorey of naturally occurring shrubs and small trees should be encouraged where possible. In many plantations colonization by hardwood species is so profuse that eventually a natural hardwood stand largely

replaces the *Pinus*; in many places this is a good thing, as the hardwood species are more valuable to local people, particularly for fodder, than the *Pinus* they replace.

Unlike most *Pinus* species, *P. roxburghii* has a certain ability to coppice, especially when the trees are small, though this is of little practical importance except in the recovery of the trees after fire damage. One feature of *P. roxburghii* in plantations is its great ability to withstand a degree of neglect and bad treatment which would kill many other species, though, of course, increment suffers. This is one of the main reasons why it is planted so extensively.

Natural regeneration

The seed is shed mostly from April to June, and is spread by the wind. It germinates best on bare ground, such as abandoned cultivation or burnt areas, but the seedlings are often able to establish themselves where there is a moderately dense grass cover. A dense ground cover of needles is however harmful, as even if the seeds germinate the seedling roots are unable to reach mineral soil.

The young seedlings need light and will often not be able to establish themselves even under an open canopy; this however varies with the site, and on hot, dry slopes they will withstand more shade than in cooler areas. Because of this strong demand for light, management by selection of individual trees is unsuitable for *Pinus* forests, if natural regeneration is needed. Either the mature trees need to be felled in groups large enough to allow seedlings to establish themselves, or a form of the uniform or shelterwood compartment system is used. The latter is the simplest method if large areas are to be dealt with, but for village forests group fellings may be preferable.

Artificial regeneration

The seed ripens between January and March; the dates tend to be earlier in the east than in the west. The cones only open in dry weather, and close again if there is rain, so the period during which seeds can be collected is often quite long. Good seed years occur irregularly. In India it is estimated that one out of every two or three years is a fair to good seed year; in Nepal the period may be even longer. In Darchula District three consecutive years of almost no seed production have been recorded. This does not mean that good seed years occur in a regular cycle; four bad seed years may be followed by two good or fair years, and so on. As good seed years occur irregularly, when they do occur as much seed as possible should be collected and stored for further use. In good years a single tree can produce 200–800 cones.

There are 8000–12,300 seeds kg^{-1} and 100 cones will produce about 450 g of seed. Properly dried seed can be stored in sealed plastic bags in the nursery for more than a year, but for storage for longer than two years refrigeration is preferable. Germination of good seed is usually high, 70–90 per cent; it usually begins 8–10 days after sowing, and is complete in another 10–20 days. In Nepal nurseries, up to 10,000 plants have been raised from 1 kg of seed, but the median figure is about half this number.

In nurseries below 1000 m seed sown in February–March should produce plantable stock by the onset of the monsoon, provided that the potting mixture is satisfactory, and there is good mycorrhizal development. At higher altitudes the seed should be sown in August–September; the Nepal–Australia Forestry Project rule of sowing before Dasain (mid-September–mid-October) is a good one. Above 2000 m *P. roxburghii* may need more than a year in the nursery; but there are probably better species for such altitudes.

Diseases and injuries

Pinus roxburghii is very susceptible to brown needle disease, which is not confined to nursery plants, but can attack trees up to 20 years old (S. Singh, 1982). Thus particular care needs to be taken to prevent this disease becoming established in nurseries where *P. roxburghii* is raised. It is also susceptible to needle rust. In parts of its range *P. roxburghii* is subject to twisted fibre, in which the fibres form a spiral up the stem, instead of running parallel to it. This is not a disease, but is due to hereditary and possibly environmental factors. Care is needed that seeds of provenances showing this defect are not collected or imported. A custom which is very injurious to *P. roxburghii* is that of wounding the stem to produce resin-impregnated wood, which is later chipped out for use as fire lighters. This in itself can so weaken the tree that it breaks off, and in addition the resin-impregnated scars are very liable to ignite and burn in forest fires. This practice should be strongly discouraged.

Provenances

In a species that occurs over such a wide range of altitude and climate considerable variation between provenances is to be expected. Among factors which are genetically controlled are the occurrence of twisted fibre (see above), branch angle and needle length (Sagwal, 1981; 1982). Growth rates and adaptation to different climatic and ecological conditions will vary between provenances, and there is some evidence that resistance to brown needle disease may also vary.

So far only a limited number of provenance trials have been planted and often from these only very early results are available. They show better growth

from Nepal provenances than from those from India or especially Pakistan. One difficulty of interpreting very early provenance trials is the period of 4–5 years before rapid height growth begins, and differentiation between the provenances takes place. For example in a trial at Lumle, three provenances were included, from Kusma, Tilhar and Sanno (near Pakhribas). After four years mean heights were 106, 114 and 115 cm respectively, i.e. there was a difference of 9 cm between the best and the worst. However after one more year the mean heights had increased to 621, 754, and 824 cm, and the difference between the best and the worst was now over 2 m (Lumle Agricultural Centre, n.d.).

In the meantime a good deal can be done to improve the quality of plantations by collecting seed locally from trees of good growth and form. In particular the large-scale import of seed from India and elsewhere, which is often supplied by contractors and hence may be of doubtful origin, should be abandoned as soon as possible, and seed should be collected from good stands within Nepal. This will not only save foreign exchange but should result in a better type of tree being planted.

Performance in plantations and rates of growth

The early growth of *P. roxburghii* pine is slow. During its first year it makes little height growth but sends out a number of shoots from the base of the stem. This slow height growth, during which the tree develops a dense, very bushy, almost spherical form and reaches about 1 m in height, continues to the fourth or fifth year after planting. There follows a period of rapid height growth.

Best height growth recorded so far is from the experiments at Lumle Agricultural Centre, referred to above, where at 1460 m altitude the mean height of the Sanno provenance, at five years old, was 8.2 m. Near Chautara, Sindhupalchok District (1500 m) Applegate *et al.* (1988a; 1988b) recorded a predominant height of 8.7 m and dbh of 11.4 cm at the age of nine years, in what they regard as a high quality stand, found to correspond to Site Quality I of the Indian yield tables for *P. roxburghii*. Their low quality site at the same age had a mean height of 4.7 m and a mean dbh of 4.8 cm. The following table (Table 48, page 636) summarizes their increment data. The current annual increment was the mean for the three years before the measurements were made. Wood includes stem and branchwood, 56 per cent and 44 per cent respectively. The mean annual increment of stem wood is equivalent, very approximately, to about 4 m³ ha⁻¹, though this may be expected to increase as the trees grow larger. In India, according to Howard (1941), the mean annual increment of Quality I natural *P. roxburghii* culminates at slightly under 13 m³ ha⁻¹, at about 50 years of age, including the yields from thinnings. The only trial from which figures have been seen in which the growth rates exceed the high-quality site at Chautara is

the one at Lumle, described above. On the other hand a number of trials have produced results worse than the low-quality site.

Table 48—Rate of growth of *Pinus roxburghii*, aged nine years, at Chautara

	High-quality site	Low-quality site
Height (m)	8.7	4.7
dbh (cm)	11.4	4.8
Wood biomass (t ha ⁻¹)	29.6	8.2
Leaves biomass (t ha ⁻¹)	6.8	1.8
Total biomass (t ha ⁻¹)	36.4	10.0
MAI (t ha ⁻¹ yr ⁻¹)	3.3	0.9
CAI (t ha ⁻¹)	6.7	2.1

At this stage no obvious correlations with altitude or other site factors can be seen, though there may be a tendency for plantations at low altitude, in the Bhabar Terai, to grow faster than those in the hills. *Pinus roxburghii* has failed in some trials at high altitudes, but at others reasonable growth has been obtained. For instance in a trial 82 months old at Tistung (about 1900 m) there were 94 per cent survivors, with a mean height of 4.0 metres and a dbh of 5.6 cm. In Baitadi in the Far Western Development Region plantations at 1760 m on a southeast-facing slope were successful, but at 1580 m on a northwest-facing slope results were poor (Margolis, 1982). In Solukhumbu District the most common cause for failure in *P. roxburghii* plantations has been planting it on sites that are too cold; however 75 per cent survival and good growth was obtained in a plantation at 2200 m on an east-facing slope in this district (J. Stewart, 1984). In the Far Western Development Region winters are colder than in the Solukhumbu area.

Some of the poor results in trials may be due to such factors as poor maintenance and the effects of brown needle disease, rather than the conditions at the particular site.

Management of plantations

This will depend a great deal on the objects of management and local demands. In some places where broadleaved species have come in under the *Pinus* species the aim may be to encourage these species by thinning out the *Pinus* to favour them. Where the aim is to maintain the plantation as a *Pinus* forest the following early management schedule (Table 49) has been suggested by Apple-

gate *et al.* (1988b), based on a plantation on a high-quality site. This table is of course an indication of one possible treatment in a particular set of conditions. The early prunings are not essential silviculturally, though they would improve the timber quality of the trees; they are important, however, in providing fuel and cattle bedding for the local villagers at an early stage in the life of the plantation. Future thinnings will depend very much on the objects of management, whether the main object is to produce fuel, poles or sawmill timber.

Table 49—Management schedule for pine forest

Height (m)	Age (yr)	dbh (cm)	Treatment schedule	Biomass harvested (t ha ⁻¹)			
				Leaves	Branch	Stem	Total
4.0	6	6.6	Prune to 10 % of stem (approx. 0.4 m)	0.3	0.9	—	1.2
5.5	7	8.2	Prune 10–20 % of stem (approx. 1.1 m)	0.3	0.9	—	1.2
7.0	8	9.8	Prune 20–40 % of stem (approx. 2.8 m)	1.7	2.6	—	4.3
8.7	9	11.4	Remove multiple stems; thin to 1300 stems/ha	0.3	0.6	1.2	2.1
9.5	10	12.8	Thin to 1100 stems/ha	0.5	0.8	1.5	2.8
Total yield up to age 10				3.1	5.8	2.7	11.6

Uses

Pinus roxburghii produces a useful constructional timber, and in former times was the main species used for house-building in Kathmandu. Nowadays *Shorea robusta*, which is more durable, is brought in from the Terai and has tended to replace *Pinus* (K.B. Shrestha, 1975) but this trend may well be reversed as the *S. robusta* forests become exhausted. Pine timber is still important for building in the hilly areas. The wood weighs about 650 kg m⁻³, air dry, and has a calorific value of about 21,200 kJ kg⁻¹ (Hawkins, 1982). It burns rapidly and produces a lot of smoke; nevertheless it is widely used, as fuel of all sorts is very scarce in many areas, and even branches removed in pruning are assiduously collected for fuel by local villagers. *Pinus roxburghii* produces a very valuable resin, used in the manufacture of turpentine, rosin, and other products. Resin is mainly tapped in the Far Western Development Region of Nepal; at one time Baitadi District was the main centre, but nowadays much is being tapped in the

southwestern parts of Doti District. Most used to be exported to India, but one large and one small distillation plants have been established in Nepal, and there are plans for more. Annual capacity will be 9000 t of rosin and 1985 t of turpentine, requiring a total input of 12,000 t of raw resin. Resin collection could provide a useful source of income for the local people, and export revenue for the country. It needs, however, to be carefully regulated to prevent over-tapping and consequent injury to the trees. Resin tapping also increases the fire risk, owing to the accumulation of highly inflammable resin at the base of the trees.

Importance in Nepal

It is by far the most widely planted forest tree in Nepal. In 1981 and 1982, 57 per cent of all trees planted by the Community Forestry Development Project were *P. roxburghii* (J.G. Campbell and Bhattacharya, 1983a); this proportion was reduced to 46 per cent in 1983, but was still four times as great as that of the next commonest species planted (Community Forestry Development Project, 1984).

The main reason for this preponderance is that it is one of the few species which will survive and grow well on the areas of very poor soil which are often the only sites available for forestry plantations in the hills; it is also a robust species which can be raised in small nurseries under less than optimum conditions. The very widespread use of *P. roxburghii* has, indeed, been often criticized, as it is of no value for fodder and is regarded in many places as an indifferent fuel. However no species has so far been found that will perform as well under community forestry conditions. One of its most important functions is as a pioneer species; once it is established other species more valuable for fuel and fodder regenerate naturally between the trees and may eventually in some cases form the most valuable part of the forest crop. Also a number of fodder species which have failed on exposed sites in the open have succeeded when planted under the shelter of *Pinus* species.

It is also a species which has been quite widely planted by individual farmers. In 1981–82 it amounted to 44 per cent of all species planted by them, but in 1983 this was reduced to 15 per cent. A good deal of this difference, however, is accounted for by increased planting of another species, *P. wallichiana*, which increased from one per cent in 1981/82 to 22 per cent in 1983. Part of the reason it has been widely planted by individuals is that seedlings are readily available in most nurseries. However it is obviously regarded by farmers as having some value.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Mader and Stewart (1983); Howard (1941) (yield tables); Lamichhancy and Joshi

(1980); Letourneux (1957); Magini and Tulstrup (1955); Prajapati (1976; 1978); Sheikh *et al.* (1982); K.B. Shrestha (1975); Streets (1962); Suri and Seth (1959); Trotter (1958); Troup (1921); Webb *et al.* (1984).

***Pinus wallichiana* A.B. Jackson**

(Syn. *P. excelsa* Wall. ex D. Don, not of Lam., *P. griffithii* McClelland)
Nepali: gobre salla, lekali salla (Solokhumbu).
Blue pine.

A large tree. Needles in bundles of five, dark-bluish green, 11–18 cm long. Cones ellipsoid, 10–15 cm long, 3.5 cm wide at first, 5–9 cm after scales have spread, scales thin and flexible. Seed with wing 1.5–3 cm long.

Occurrence

It is found in Nepal between 1800 and 3600 m, and very occasionally to 4400 m. It is fairly widely distributed in the midland zone, between the foothills and the main Himalayan range, where, at its lower altitude limits, it is often mixed with *P. roxburghii*, but in general at these altitudes *P. roxburghii* will be found on south-facing slopes and *P. wallichiana* on north-facing slopes. It tends to be absent from the wettest parts of the midland zone. It is very characteristic of abandoned fields and grazing land. It is abundant in the inner dry valleys, such as in the Humla-Jumla, and the edges of the arid zone round Jomsom, where it is found under rainfall of 750 mm or less; it is also very common in the Solokhumbu area. Outside Nepal it extends as far as Afghanistan in the west, and Bhutan in the east, though it is absent from Sikkim.

Silvicultural characteristics

Pinus wallichiana is capable of growing into a very large tree and heights of over 50 m have been recorded in India. Like all pines it is a strong light-demander. It prefers a well-drained, porous soil, and will grow on limestone provided the soil above the rock is deep enough. The seedlings are frost-hardy. *Pinus wallichiana* is considerably less fire-resistant than *P. roxburghii*, but young trees scorched by fire will sometimes shoot from the base. In India small seedlings may suffer from drought after the end of the monsoon, and again in April and May. They can withstand competition from shrubby growth, but dense, matted grass is harmful to them. They are very easily damaged by browsing.

Natural regeneration

Where conditions are favourable *P. wallichiana* regenerates profusely. The seeds are shed at the end of the monsoon, in October and November, and are spread over fairly large distances, up to 200 m or more, by the wind. They stay on the ground over winter and begin to germinate at the beginning of the rains. During this dormant period they are susceptible to being eaten by birds.

Best regeneration is on newly exposed, loose, porous soil, such as abandoned cultivation and landslips. It also is profuse on recently burnt areas. The seedlings can grow through shrubs and fairly heavy weed growth; bracken (*Pteridium aquilinum*) indicates particularly good conditions for regeneration. Though the seedlings will persist for some years, under moderate shade growth is slow, and for good development full light is needed. Opening up oak forest by lopping for fodder is often followed by dense regeneration of *P. wallichiana* in the gaps.

Artificial regeneration

The seed ripens in October to November; there are from 15,000 to 30,000 seeds kg⁻¹. Dry seed can be stored for up to a year in sealed plastic bags. Napier and Robbins (1987) found that germination of seed thus stored was 54 per cent initially, 79 per cent after nine months, 62 per cent after a year, but only 29 per cent after 15 months; thus to store seed for more than a year refrigerated storage is desirable. Seed stored in cloth bags began to lose viability rapidly after six months.

In warm weather germination usually begins after about three weeks, and is complete about ten days later, but in high altitude nurseries seed sown in winter will frequently not germinate until March. The seedlings are rather slow growing, and at lower altitudes, say at 1500 m, will need 15–16 months in the nursery; that is, the seed should be sown at the end of the cold period, about March. Between 1500 and 2000 m 22–23 months will be needed in the nursery, and above 2000 m 27–28 months.

Normal plantation techniques are used. Some trials have been made of the use of bare-root plants, but results from plants in polypots have been better; for instance at Tistung (1900 m) survival of bare-root, unpruned plants was 23 per cent; of bare-root plants root pruned in the nursery 44 per cent; and of plants in polypots 72 per cent. Plants removed from the polythene bags before being transported from the nursery to the field, an undesirable but by no means unknown practice, have survived very badly, as have natural seedlings collected from the forest and planted into polythene bags.

Trials of different planting dates at Pakhribas gave 100 per cent survival for seedlings planted from April to August, 67 per cent for September, 75 per cent

for October and 92 per cent for November (L. Joshi and Sherpa, 1992). This indicates that the planting dates for *P. wallichiana* are more flexible than those for many other species. However during the early rains is still the safest time to plant; apart from survival, late planting is likely to result in lower rates of increment in the first year.

Performance in plantations and rate of growth

Survival in trials has usually been good, especially at altitudes of over 2000 m; below 1600 m survival in some cases has been moderate to poor, though other reasons than altitude may have contributed to this. It is interesting that survival rates of 89 per cent have been recorded from Thulo Chaur, Mustang, at 2550 m an area of low rainfall (R.B. Joshi, 1985).

The rate of growth is slow, and in most comparative trials *P. wallichiana* has had the lowest rate of height growth of all pines tested. As in *P. roxburghii* growth for about the first four years after planting is very slow, after which it increases however in general, best height growth at the age of ten years is under 5 m. The recorded exceptions are at altitudes below the natural range for *P. wallichiana*; at Gharamdi, near Lumle (1450 m) mean height increased from 1 m at four years to 5.1 m at five years (Lumle Agricultural Centre, n.d.), and at Godavari (1520 m) a mean height of 6.3 m at eight years was recorded.

Raese (1986) has produced yield and volume tables for *P. wallichiana* in Jumla District. These are for natural stands in an area of relatively low rainfall; plantations on better sites may be expected to grow rather faster. The following figures (Table 50, page 642) are extracted from these tables; the mean annual increment includes yields from thinnings. Raese's thesis also includes biomass tables and branchwood yields. The yields are low; a good conifer plantation in the United Kingdom will have a maximum mean annual increment of 15 m³ ha⁻¹ or more.

Provenances

In a species growing in such a wide range of altitudes and rainfall considerable differences between provenances are to be expected; however very few comparative trials have been made. At Kharidunga (2400 m) the best three provenances, based on growth of young trees, were from Tashunga, in Solokhumbu; Daman in Makwanpur; and Rara, in Mugu District. At Tistung (1900 m) the best three were from Rasumwa; Melung, in Dolakha District; and Taplejung. In the Tistung trial provenances from Pakistan gave poorer results than those from Nepal, and suffered more from brown needle disease. It is not possible to draw many conclusions from these very limited trials.

Table 50—Yield and volume table for *Pinus wallichiana*

Age (yr)	Site Quality I					Site Quality II					Site Quality III				
	Height (m)	Diameter (cm)	Stems (ha ⁻¹)	Standing volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Height (m)	Diameter (cm)	Stems (ha ⁻¹)	Standing volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Height (m)	Diameter (cm)	Stems (ha ⁻¹)	Standing volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)
10	2.7	2.3	many	0.0	0.0	1.8	0.8	many	0.0	0.0	1.2	0.0	many	0.0	0.0
20	10.1	10.9	1764	0.0	0.0	7.3	6.6	3014	0.0	0.0	5.1	4.3	4370	0.0	0.0
30	15.8	18.8	1025	23.0	0.7	12.5	13.0	1400	5.6	0.2	9.8	9.1	2063	0.0	0.0
50	26.2	34.5	526	152.0	2.1	21.0	25.4	724	89.2	1.9	17.1	19.0	966	50.6	1.1
80	37.5	51.3	343	363.0	5.4	31.1	42.7	410	256.3	3.7	25.3	34.5	494	171.3	2.5
100	41.1	57.1	296	436.0	5.4	35.0	48.8	358	342.7	4.2	28.6	41.4	420	246.4	2.9

Note: Standing volume and MAI for stem timber only.

Diseases and injuries

The susceptibility of *P. wallichiana* to brown needle disease has already been referred to. It can be severe in the nursery and on young seedlings, but once the trees have started to grow quickly, at about four years old, the damage caused becomes less serious. The needles are also attacked by *Dothistroma* needle blight, caused by *Mycosphaerella pini*, but so far no reports of serious damage have been seen. *Pinus wallichiana* needle rust (*Coleosporium barclayense*) has also been recorded on seedlings and trees up to ten years old; it causes needle necrosis and needle cast, but again there have been no reports of serious damage. Although regeneration is often profuse on burnt areas, young *P. wallichiana* is very liable to be damaged by fire. It also suffers greatly from grazing. Another harmful practice is the removal of slivers of resinous wood from the stems for use as torches and for lighting fires.

Uses

The timber is of better quality and is more durable than that of *P. roxburghii*, and in the parts of Nepal where the tree is plentiful it is widely used for house building. It weighs about 480 kg m⁻³ and has a calorific value of about 20,900 kJ kg⁻¹ (Hawkins, 1982). Where it occurs naturally it is highly valued as a fuelwood, and resin-impregnated spills from the trunk are used for lighting in remote areas. It produces a good resin, but the yield is less than that from *P. roxburghii*; it has not so far been tapped for resin in Nepal.

Importance in Nepal

It is an important species for afforestation at higher altitudes, for though it is slower growing than *P. roxburghii* it is more cold-resistant and produces a better timber. From one per cent of the total number of seedlings planted by the Community Forestry Development Project in 1981–1982 it rose to 11 per cent in 1983, when it was the second most common species planted. The mean survival rate, however, declined from 81 per cent in 1981–1982, to 73 per cent in 1983 (J.G. Campbell and Bhattarai, 1983a; Community Forestry Development Project, 1984).

References: M.W. Campbell (1983a); Champion (1929); Chaturvedi (1973c); Gamble (1922); Lamichhaney and Joshi (1980); J. Stewart (1984); Suri and Seth (1959); Streets (1962); Trotter (1958); Troup (1921).

Exotic pines—major species

Pinus maximinoi H. Moore

(Syn. *P. pseudostrobus* auct. non Lindl., *P. tenuifolia* Benth. non Salisb.)

A number of provenances of *Pinus pseudostrobus* were introduced to Nepal in the 1970s. Some of these were found to grow very rapidly, and it was later discovered that these fast-growing provenances, and indeed probably all except those from Mexico, and K75 from Tecpan, Guatemala, were in fact *P. maximinoi*. This five-needled pine is found in Mexico, Guatemala, Honduras, Nicaragua and El Salvador, at altitudes of between 700 and 2400 m, on soils ranging from deep clays to shallow degraded soils. The provenances tried in Nepal come from areas with rainfalls of between 900 and 1700 mm, which is heaviest in summer. The species is reported to be unable to withstand prolonged periods at sub-zero temperatures; however it will tolerate a certain amount of frost, as is shown by its performance in Nepal at altitudes of up to 2000 metres. In addition it withstood an unusual spell of snow and cold at Tistung (1900 m) which caused 50 per cent deaths in a Guatemalan provenance of *P. pseudostrobus*. It appears not to be affected by brown needle disease, nor does it suffer from the shoot dieback which affects *P. patula*. It tends, however, to be of relatively poor form, with coarse branching.

In nearly all comparative trials in Nepal, at altitudes from 250 to 2000 m, provenances of *P. maximinoi* have grown faster than any other pine. Details of some of these trials can be seen in Neil (1991). At Pakhribas (1940 m) three provenances of *P. maximinoi* were included in a trial. At ten years of age the following results were obtained (mean over all provenances) (Wallace, 1989b).

• Mean height	9.2 m
• Mean diameter	14.7 cm
• Volume per hectare	138 m ³
• MAI	13.8 m ³
• Wood biomass, dry weight	45.7 t ha ⁻¹

At 11 years old an overdue thinning was made, reducing the number of trees from 2050 to 1350 stems ha⁻¹; this produced the equivalent of 41 m³ ha⁻¹ of stem timber (17.5 t ha⁻¹ dry matter) plus 6.3 t ha⁻¹ of branchwood and 1.7 t ha⁻¹ of foliage. Height differences between provenances were not significant; in diameter the Tatumbla, Guatemala provenance (the best) was significantly greater than Volcan Yali, Nicaragua, but did not differ significantly from San Juan, Nicaragua. The Volcan Yali provenance, however, had the best form (stem straightness, branch diameter, branching angle). The localities listed in

Neil's paper are confused, and should be as follows: Site A in the table is E, Chitripani; site B is A, Syangja; site C is B, Lauke; Site D is C, Tistung; and Site E is D, Kharidunga. The following data (Table 51) are available from plots three years old or more.

Table 51—Growth of provenances of *Pinus maximinoi*

Site	Altitude (m)	Provenance	Age (yr)	Survival (%)	Mean height (m)	Mean diameter (cm)	Remarks
Chitripani	450	San Rafael, Nic.	7.8	63	13.0	15.1	
Ganesh-pur	1100	Dulce Nombre, Hond.	4.7	83	4.2	5.4	2nd of 3
		Cofradia, Hond.	5.4	82	8.1	—	Best in trial
Lauke	1400	Jinotega, Nic.	4.0	68	3.8	—	
Lumle	1460	Volcan Yali, Nic.	4.0	—	2.1	—	
Tistung	1900	Dulce Nombre, Hond.	3.8	100	4.5	—	Best in trial
		Dulce Nombre, Hond.	6.8	100	11.2	10.8	Best in trial
Pakhribas	1900	Tatumbula, Hond.	5.0	100	4.3	8.2	Best in trial

Apart from the provenance trial at Pakhribas referred to above, the only other provenance trial of which results have been seen was at Salle, also near Pakhribas (2000 m). Sherpa *et al.* (1992) have given data from this trial two years after planting, which is rather young for comparison of growth in pines. The best provenance however was from Tatumbula, with 100 per cent survival and a mean height of 1.04 m, followed in order of height increment since planting by Dulce Nombre, Jinotega, San Rafael, Loma de Ochoa and Volcan Yali. The last had 94 per cent survival and a mean height of 73 cm.

In trials in southern Africa it was found that the provenances from Dulce Nombre, Tatumbula and Cofradia gave consistently higher volume production than other provenances (Crockford *et al.*, 1991). As far as they go results from Nepal are consistent with this. *Pinus maximinoi* is a potentially valuable species

for planting at all altitudes up to 2000 m, and can be regarded as a faster-growing alternative to *P. patula*. The relatively poor form may be a drawback.

***Pinus patula* Schiede & Deppe**

Nepali: patula salla, patle salla, amerika salla.

A three-needled pine, leaves 18–20 cm long, very slender, hanging down on each side of the branches. Cones 8–10 cm long, oblique, curved, shining pale brown.

Origin

It is native to the mountains of eastern Mexico, between 18°N and 26°N, and between 1650 and 3000 m. In this area the rainfall ranges from 1000 to 1500 mm and occurs mainly in summer, with a relatively short dry season. Occasional frosts occur. It has been very widely planted in South Africa and the highland areas of east Africa, and to a lesser extent in India, Australia, South America and elsewhere. It was introduced into Nepal before 1968 and is now well established as a plantation species; in some areas it has begun to produce seed.

Silvicultural characteristics

In its native habitat it grows into a large tree, up to 30 m in height by 1.2 m in diameter; as an exotic it has reached 50 m in height. It tends to branch rather heavily. It is fairly tolerant of poor soils, provided they are acid, but is very sensitive to boron deficiency (see Diseases and disorders, page 647). It is frost-tolerant, but seedlings in nurseries should be protected against frost. In Nepal it is best suited for planting between 1500 and 2500 m. It has a thin bark and is sensitive to fire up to at least the pole stage.

Artificial regeneration

Only small quantities of seed are available from within Nepal, and the bulk must be imported. There are usually between 100,000 and 150,000 seeds kg⁻¹; thus for a pine it has a light seed. The seed can be stored in sealed plastic bags for more than a year without serious loss of viability. The germination percentage should be about 80, but much lower figures have been recorded in many Nepalese nurseries, perhaps due to poor quality seed. Up to 90,000 plants have been raised per kilogram of seed, but the average is much lower. Germination usually begins after 2–3 weeks, and is completed 10–20 days later.

As the seed is small J. Stewart (1984) recommends sowing it in beds, and later pricking the seedlings out into polythene bags. Below 1500 m seed sown

in September should give plantable stock by the onset of the next monsoon, but at higher altitudes the seed should be sown about March, and the plants kept for 15–16 months in the nursery. Some problems have been encountered in nurseries from seedlings being stunted and the leading shoot dying. The cause is unknown (Anon., 1983a).

Plantation techniques

There are no particular difficulties in planting. Good results were obtained at Tistung by planting in V-shaped pits about 15 cm deep, made by agricultural hoes, and an area about 20 cm radius round the plants (H.B. Thapa, 1987). In another experiment there were no significant differences from planting in pits ranging from 15 cm x 15 cm x 15 cm to 50 cm x 50 cm x 50 cm.

At Tistung (1930 m) there were no survivors from bare-root plants, unpruned in the nursery; 35 per cent from bare-root plants, root pruned in the nursery; and 98 per cent from polypot plants. At Kharidunga (2700 m) in winter planting after four months bare-root plants had 12 per cent survival, and polypot plants 100 per cent.

Disease and disorders

Seedlings of *P. patula* are susceptible to brown needle disease, but as they grow older the plants rapidly become less susceptible. Some plantations have been seriously affected by dieback of the leading shoot, which may spread some distance down the stem, producing a stunted misshapen tree. The symptoms closely resemble those caused in other countries by drought-induced boron deficiency, but this has not yet been proved to be the cause of dieback in Nepal (Hudson *et al.*, 1988). Three weak pathogenic fungi, *Phomopsis occulta*, *Potebniamyces coniferarum* and *Coniothyrium fuckelii* were found on dead and dying shoots, but these may well be secondary, occurring when the shoots have already been weakened by other causes.

Many Nepal soils are low in boron, but examination of the soil at Bal Ban, about 1800 m, showed no difference in boron content between areas where dieback was present, and areas free from dieback, though it was low in both cases (Howell, 1988a). Similarly needles from areas of healthy trees and areas of stunted trees had about the same, low, boron content. Dieback due to boron deficiency is associated with drought, and water availability may be complicating the picture. Previous trials of the effect of boron on the growth of pines have been unsatisfactory, and properly conducted trials are desirable. The boron fertilizer should be applied to the ground, rather than as a foliar spray, as the effects of the latter tend to be transitory. If boron deficiency is present it can be prevented by applying borate fertilizer in small pits dug about 30 cm from the

tree, preferably 2–3 weeks after the trees have been planted. The borate should not be allowed to come into contact with the tree. The best rate of application needs to be found out by trial; in parts of east Africa 10 g per tree (16 kg ha⁻¹) have been found adequate, but Neville (1982) reports that some trees treated at this rate were again showing dieback 1.5–2.5 years after the original application. This means that a repeat dose will be needed, but application of larger quantities initially, of up to 40 g per tree, might avoid the need for this.

Performance in plantations and rates of growth

Survival has been generally good, over 80 per cent in most sites. Early growth is rapid, and there appears to be less tendency to slow growth in the first few years after planting than is shown by some other species of pine. On a good site trees may reach 2 m in height after two years. Seven-year-old trees at Lower Nagarkot (1760 m) averaged 10.6 m in height by 12.4 cm in diameter, and at Upper Nagarkot (2000 m) 9 m in height by 11.7 cm in diameter (M.R. Joshi and Wyatt Smith, 1982). Figures from Tistung (1800 to 2000 m), calculated from regression equations, are similar, as follows (Table 52). Neither site would be considered particularly fertile. These rates compare favourably with data from Malawi (T.J. Wormald, 1975) and if maintained would indicate an eventual mean annual increment of about 19 m³ ha⁻¹.

Table 52—Growth of *Pinus patula* at Tistung

Age (yr)	Mean height (m)	Mean diameter (cm)
3	3.4	6.3
5	6.8	9.3
7	10.2	12.4

Neville (1985b) gives data on growth and pruning yields for trees 3.5 and 4.5 years old; pruning yields (fresh weight) were 12 and 23 t ha⁻¹ respectively. H.B. Thapa (1987) gives the following data (Table 53) from Tistung, age 4.5 years. The harvest consisted of pruning to one third total height at age 2.5 years and one third to a half total height at ages 3.5 and 4.5 year; and a systematic thinning of a quarter of the stand at age 4.5 years. The MAI of wood, which includes branchwood, was 9.5 t ha⁻¹.

Table 53—Yields and standing crop of *Pinus patula* at Tistung (t ha⁻¹, oven-dry weight)

	Cumulative harvest	Standing crop	Total
Foliage	13.8	7.8	21.6
Wood	17.4	25.2	42.6
Total	31.2	33.0	64.2

Provenances

Comparative trials of different provenances have begun only recently. Wallace (1989a) gives results from trials of 12 provenances (plus one of *P. greggii*) aged 2.9 years at Pakhribas (1950 m). At this early stage it is difficult to draw conclusions about the best provenance. Best height growth (199 cm) was given by L 764 from Pinal de Amoles, Mexico, followed by L 340 from Zacualtipan and L 767 from near Acaxotitlan. Provenances from seed orchards in New Zealand and South Africa fell in the middle of the scale.

Uses

The wood varies considerably in density, from 370 to 600 kg m⁻³; older trees tend to produce denser wood than younger trees. The wood near the core of the tree tends to be rather weak and soft, but the outer wood has better strength properties. It is used for boxes, cheap joinery, and construction. Its fuelwood is presumably similar to that from other pines.

Importance in Nepal

Pinus patula is a popular species for planting, because of its very rapid growth, second only to *P. maximinoi*. In many places it could replace *P. roxburghii* in plantations and give considerably higher yields; its main disadvantages are its susceptibility to dieback and to fire damage. Its survival rate in plantations has usually been quite good; in the Community Forestry Project plantations it averaged 73 per cent in 1981–1982, and the same in 1983 (J.G. Campbell and Bhattarai, 1983a; Community Forestry Development Project, 1984). In well-tended plantations on suitable sites survival rates of over 80 per cent can be expected. It is also fairly popular for planting by individual farmers because of its rate of growth, and also perhaps because of its novelty.

References: A monograph has been prepared by T.J. Wormald (1975). Other references: M.W. Campbell (1983a); Champion and Seth (1968b); J. Evans (1982); Ghosh (1977); Lamichhaney and Joshi (1980); Letourneux (1957);

Magini and Tulstrup (1955); Napier and Robbins (1989); Neil (1989a); Neville (1982); J. Stewart (1984); Streets (1962); Webb *et al.* (1984).

Pinus patula subsp. *tecunumanii* see *P. tecunumanii*.

Other *Pinus* species

Pinus caribaea Morelet

This species has three distinct varieties, *P. caribaea* var. *caribaea*, from Cuba, var. *bahamensis* Barr. and Golf, from the Bahamas, and var. *hondurensis* Barr. and Golf, which occurs in Central America from northeastern Nicaragua through Honduras and Guatemala to Belize. These pines have been widely planted in tropical lowland areas because of their rapid growth and the relative ease by which they can be established, but so far have only been planted in small-scale trials in Nepal.

Although *Pinus caribaea* in nature grows at an altitude of up to about 900 m, it has usually been considered as a plantation species for tropical lowlands. In Nepal, however, results are rather contradictory. Var. *hondurensis* had good survival and height growth at Godavari (1520 m) and Lower Nagarkot (1700 m); at Upper Nagarkot (2000 m) its survival was slightly poorer (79 per cent). It failed at Lauke (1450 m) and Tistung (1800 m). All three varieties were killed by frost with a temperature of -8.5°C in Brazil, but var. *bahamensis* and var. *caribaea* suffered relatively little damage at -2°C , compared with var. *hondurensis* (Greaves, 1979). All three varieties will grow on soil of low fertility, though severe phosphate deficiency retards growth. Var. *hondurensis* and var. *caribaea* prefer acid soil, with a pH of about five, but var. *bahamensis* grows naturally on shallow soils over coral limestone, where the pH may exceed eight.

In early trials at Chitripani, in a dun valley at 450 m, two provenances of var. *bahamensis* both survived better and grew faster than provenances of var. *hondurensis*, contrary to experience in most parts of the world. The better performance of var. *bahamensis* at this area may be due to soil factors. Some dun valley soils have a rather high pH, which would favour var. *bahamensis*. In later trials at Adabhar (250 m), where the soils are mostly almost neutral (approximately pH 7), the following results (Table 54) were obtained, at the age of 5.6 years. The heights are those from one replication only, and hence are indicative only. However the data show that, in this area, at least some provenances of var. *hondurensis* grow faster than var. *bahamensis*, which is more in agreement with experience elsewhere. These figures also illustrate the considerable variation which can be found in the growth of different provenances of *P. caribaea*, and large-scale international provenance trials have been under-

taken: see Greaves (1979). There is also considerable variation in tree form. In most trials in Nepal other species have grown faster than *P. caribaea*. However if large-scale pine plantations in lowland Nepal were ever envisaged, further trials of this species, including a range of provenances, would be desirable.

Table 54—Survival and growth of two varieties of *Pinus caribaea* at Adabhar

Variety	Provenance	Survival (%)	Mean height (m)	Mean dbh (cm)
<i>bahamensis</i>	Andros	86	4.2	7.6
<i>hondurensis</i>	Alamicamba, Nic.	89	4.3	9.8
	Trojes, Honduras	81	7.8	9.1

Var. *hondurensis* has 50,000 to 80,000 seeds kg⁻¹. In Terai nurseries seed sown in October will produce plantable stock by the beginning of the monsoon.

References: Lamb (1973) has written a monograph of the species. Other references: Ghosh (1977); M.R. Joshi (1983); Lamichhaney and Joshi (1980); Laurie (1974); National Academy of Sciences (1983); Neil (1989a); Paul (1972); Robbins and Hughes (1983); Streets (1962); Webb *et al.* (1984).

Pinus contorta Douglas. A two-needled pine from the Pacific coast of North America, from Alaska to California. It has been tried on a few sites; at Khari-dunga (2700 m) there were 76 per cent survivors with a mean height of 34 cm at the age of 29 months. No results are available from trials at other sites. Two or three specimens in the Arboretum of the Royal Botanic Garden at Godavari are not thriving.

Pinus densiflora Siebold and Zucc. A two-needled pine from Japan. At Tistung (2000 m), at the age of 6.8 years there was 83 per cent survival with a mean height of 3.5 m and a dbh of 7.5 cm; the height is less than that of *P. roxburghii* in the same trial though the diameter is greater. In other trials at Chitripani, Adabhar and Syangja growth and survival were rather poor. No particular reason to plant it.

Pinus echinata Miller. Native of the southeastern United States, planted at Godavari in 1973 but failed.

***Pinus elliottii* Engelm.**

Slash pine.

Needles in threes, sometimes in twos, 20–30 cm long, with sheaths 12–18 mm long. Cones shortly stalked, oblong-conical, 7–16 cm long, with a minute recurved prickles on each scale. Native to the south-eastern United States. A number of trial plots and small plantations have been established in Nepal since the 1960s some of which, at altitudes from 300 to 2000 m, are growing quite well. The mean height growth has ranged from 50 cm to 107 cm a year, and in good plantations a diameter growth of 1 cm or slightly more per annum can be expected. Up to the age of ten years *P. elliottii* grows faster than *P. roxburghii* though it is possible that *P. roxburghii* may catch up later. Both grow considerably slower than *P. maximinoi*, *P. tecunumanii* and *P. patula*. Growth at Chitripani, in the Siwaliks, is more rapid than at Tistung (2000 m). There are about 38,000 seeds kg⁻¹. *Pinus elliottii* is reported to be resistant to brown needle disease; the needles may be infected, but the resulting damage to the plant is slight. Partly because of this disease-resistance Neil (1989a) considers that slash pine could be considered as a substitute for other susceptible species. However in all areas where it has been tried there are other species which give a considerably higher volume yield, at least during the first ten years in the plantation.

References: J. Evans (1982); Ghosh (1977); Magini and Tulstrup (1955); Streets (1962); Webb *et al.* (1984).

***Pinus gerardiana* Wall.**

Nepali: gole simta (the seed).

Chilghoza pine.

Native of the western Himalaya from Afghanistan to the Sutlej, prized for its edible seed. Mentioned by as a possible species for the Far Western Development Region of Nepal, but it is a species growing where there is a considerable winter snowfall and the likelihood of success in predominantly summer rainfall areas is low. See also Troup (1921).

***Pinus glabra* Walter.** Native of the southeastern United States. Planted at Godavari in 1973, but only 44 per cent survival after 30 months.

***Pinus greggii* Engelm.**

Needles in threes, 9–12 cm long. Young shoots whitish, or olive with a whitish bloom. Buds bright chestnut. Cones very oblique at base, 10 cm by 4 cm, scales with a minute spine. A Mexican species related to *P. patula* but which grows at higher altitudes (2000 m) and on poorer soils. At Tistung in Nepal it withstood an abnormal snowfall and cold spell rather better than *P. patula*. Its form tends to be poorer, as has been shown when it was included in *P. patula* provenance trials. At Tistung trees adjacent to plots of *P. patula* with shoot dieback were unaffected, but at Pakhribas it was affected by this disorder (Hudson *et al.*, 1988).

Neil (1990f) measured a stand 5.6 years old at Tistung (1900 m). Survival was 96 per cent, mean height 7.9 m, mean dbh 11 cm, and volume overbark, down to 2–3 cm top, 91.2 m³ ha⁻¹, equivalent to a mean annual increment of 16.3 m³ ha⁻¹. The stem volume was equivalent to 36.6 t ha⁻¹ oven-dry weight (1 m³ = 401 kg). In addition there were 13.5 t ha⁻¹ of branchwood and 10.9 t ha⁻¹ of foliage. This volume increment ranks among the highest at Tistung. The plot was thinned mechanically at the time of measurement, by removing 50 per cent of the trees. This produced 19.3 t of stem wood, 5.2 t of branchwood, and 6.6 t of foliage ha⁻¹, all oven-dry weight. In two other trials the growth of *P. greggii* was exceeded by insignificant amounts by one provenance of *P. patula* in each trial; other *P. patula* provenances had poorer growth. Thus *P. greggii* has considerable interest as a possible alternative to *P. patula*.

References: Neil (1990f; 1991).

***Pinus kesiya* Royle ex Gordon**

(Syn. *P. khasya* Royle, *P. insularis* Endl.)

A three-needled pine. Leaves 10–20 cm long. Cones 7–8 cm by 4–5 cm; seed wing about four times length of seed. This subtropical pine has a wide and discontinuous distribution, including the Khasi Hills in India, eastern Burma through Thailand to Vietnam, and Mindanao in the Philippines; in the Philippines it is often called *P. insularis*. It occurs naturally at altitudes of between 800 and 2000 m. In Thailand it is mainly found between 1000 and 1500 m under rainfall of between 1300 and 2000 mm, with a six-month dry season, often on shallow soil on ridge tops in the *Schima-Castanopsis* zone. In its natural range it is rarely subject to frost but when planted as an exotic it will survive light frosts once the seedlings are established. One provenance (Zimbabwe) was severely damaged by an exceptional period of snow at Tistung (1700 m). It will tolerate poor and eroded soils. It is easy to raise provided care

is taken to ensure good inoculation with mycorrhiza. It is very fire-tolerant, and trees 2 m tall will recover after fire provided the leading shoot is not burnt.

It has been included in a number of trials in Nepal. In the Nepal–Australia trials at Godavari (1590 m) it was the fastest growing pine planted, reaching a height of 8.5 m by a diameter of 11.1 cm in six years. Unfortunately in these trials, especially at Godavari, there was a tendency for the trees to bend over and sometimes to become almost horizontal. This may have been partly a provenance effect; the seed used in the trials came from Zambia, where one widely planted provenance tends to have stems bowed at the base. *Pinus kesiya* has also been included in trials at Tistung. In these trials it has survived and grown well, but other species have grown faster. The provenances tried up to the present are either from the Philippines, or from plantations in Zambia. It might be worth trying some of the better provenances from Thailand. The species is not suitable for plantations below 500 m altitude. There are from 40,000 to 60,000 seeds kg⁻¹.

References: Ghosh (1977); Lamichhaney and Joshi (1980); Laurie (1974); Letourneux (1957); Magini and Tulstrup (1955); Streets (1962); Troup (1921); Webb *et al.* (1984).

***Pinus merkusii* Jungh and De Vries.**

Leaves in twos, 15–25 cm long, with grey ragged sheaths. Cones 5–8 cm long on stalks 1 cm long. A native of Burma, Thailand, Vietnam, Sumatra and the Philippines, which has been planted in a number of tropical countries with a good deal of success. Its chief drawback is its grass stage, similar to that of *P. palustris*, in which the seedlings remain for up to four years before they make any height growth. Provenances from the Korat Plateau, Thailand, and Sumatra are free from this habit. It failed in trials at Adabhar, but this was using seedlings only 3 cm high in an area with much *Imperata*. Suitable for low altitudes only.

References: Laurie (1974); Letourneux (1957); Magini and Tulstrup (1955); Troup (1921).

***Pinus montezumae* Lamb.** Leaves in fives, occasionally threes. Native of Mexico between 1200 and 3600 m. Tried at Khawa in 1973 but failed.

***Pinus oocarpa* Schiede.**

A five-needled pine; needles broad and stiff, with scaly black sheaths; cones almost as broad as long, with a flattened base; bark thick, greyish-black, plated.

The most promising provenance of *P. oocarpa* imported into Nepal, from Yucul, Nicaragua is actually *P. tecunumanii* (*P. patula* subsp. *tecunumanii*) q.v. However some true *P. oocarpa* provenances have also been introduced, and have grown reasonably well, though not so fast as *P. tecunumanii*. At Adabhar (250 m) provenances from Dipilto, Nicaragua, and Lagunilla, Guatemala, averaged 7.7 m in height at 5.6 years. The former had a mean dbh of 9.1 cm, and 69 per cent survival; the latter 9.3 cm dbh, and 72 per cent survival. A third provenance from La Union, Honduras, did less well. Less good growth was obtained at Syangja (1100 m), while at Tistung (2000 m) all failed. Thus it is moderately promising in the Bhabar Terai zone, but other species have more rapid growth and better form.

***Pinus palustris* Miller.**

Longleaf pine.

A three-needled pine; needles 20–45 cm long; buds up to 5 cm long; bud scales persistent at apex of second year branchlets. Native of the southeastern United States. It has been included in a number of trials, but the main problem is that it has a grass stage, with the seedlings producing numerous long grass-like needles but making no height growth for a number of years after planting. One or two plots have been seen where it has grown out of this stage and appears healthy. It has similar climatic requirements to *P. elliottii*, and the latter would generally be preferred in plantations.

***Pinus pseudostrobus* Lindl.**

Leaves in fives, pendulous, 18–20 cm long; native of Central America and Mexico. The better provenances imported as *P. pseudostrobus* are in fact *P. maximinoi*, q.v. However the Tecpan provenance of *P. pseudostrobus* has done tolerably well in trials at Chitripani, Tistung and Pakhribas. At Pakhribas the volume of this provenance (estimated from the product of diameter squared and height) was 71 per cent of that of the Tatumbla provenance of *P. maximinoi*. However as *P. maximinoi* grows faster there seems to be no reason to choose *P. pseudostrobus*.

***Pinus radiata* D. Don.** A three-needled pine, native of California, and widely planted in New Zealand, Australia, South Africa, Chile and the highlands of east Africa. It was included in trials at Chitripani, Gokarna and Godavari but has failed in all of them.

Pinus L.

Pinus strobus L. A five-needled pine, native of the United States and Canada; a subspecies in Mexico. Planted in trials in Chitripani in 1971 and 1972, but failed.

Pinus strobus var. *chiapensis* Mart. From Mexico. Failed at Tistung (1500 m). It was proposed for trial in Solokhumbu in 1985 (J. Stewart, 1984).

Pinus taeda L.

Loblolly pine.

Three-needled pine; needles 15–17 cm long, grey green; shoots glossy, olive-brown; cone armed with stoutly based curved spines. Native of the southeastern United States, from New York to Tennessee and Texas. It has been planted in a number of trials, especially in the Kathmandu Valley, where top heights ranged from 4.3 m to 6.7 m at ten years old, and diameters of the larger trees from 10.4 to 15 cm at the same age. The best results were at Godavari, where the ten best trees per plot at nine years old averaged 6.7 m in height and 15.5 cm in diameter, with 57 per cent survival. These growth rates were slightly below those of *P. elliotii* and a little better than those of *P. roxburghii* but the latter had a much better survival rate of 93 per cent.

Pinus tecunumanii Eguiluz and Perry

(Syn. *P. patula* Schiede and Deppe subsp. *tecunumanii* (Eguiluz and Perry) Mittak and Styles; *P. tecunumanii* Schwerdtf., not validly published; *P. oocarpa* auct. non Schiede).

Leaf bundles mostly with four needles, a few with three or five; needles slender, with slender smooth sheaths. Bark reddish, flaky. Cones considerably longer than broad, apex pointed, base rounded. Some botanists regard this as a subspecies of *P. patula* (see page 646) but its climatic and ecological requirements are very different and it is more convenient to regard it as a separate species. It occurs naturally in Guatemala, Nicaragua and Honduras. It was originally introduced to Nepal as the Yucul provenance of *P. oocarpa*. It is more suited for planting in the lowland tropics than is typical *P. patula*, and is considerably more frost-tender than that species. At Tistung (2000 m) in a unusual cold spell in 1984, all the *P. tecunumanii* were killed, while 80 per cent of the true *P. patula* survived. It is susceptible to brown needle disease. There are about 90,000 seeds kg⁻¹. It has grown well in trials in the Bhabar Terai zone, though survival has in some cases been only moderate. At Chitripani (480 m) at 7.8 years the mean height was 12.9 m and dbh 13.0 cm, but survival was only

43 per cent. The height growth was second, but by an insignificant amount, to that of *P. maximinoides*. In another trial at Chitripani it was 4.1 m high at 3.3 years, with a survival rate of 71 per cent. At Adabhar (250 m) at 2.6 years the mean height was 3.6 m and survival 88 per cent. It has a very good form. If large-scale pine plantations were planned in the lowlands of Nepal this certainly would be one of the species to be considered.

References: Eguiluz-Piedra (1986); McCarter and Birks (1985); Neil (1989a); Webb *et al.* (1984).

Pinus torreyana Parry. Five-needled pine, native of California. Tried in Khawa in 1973 but failed.

Pinus virginiana Miller. Two-needled pine, native of eastern United States. Planted at Godavari in 1973, but survival and height after 30 months were only 21 per cent and 18 cm respectively. Also tried at Chitripani in 1974.

Comparative growth rates of pine species

Table 55 (pages 658–660) is an attempt to indicate the differences in pine growth rates more clearly than is shown by data on height and diameter only. Except where otherwise stated the estimated volume is derived from the percentage survivors, mean heights and mean basal areas of the trees, converted into volumes by using a form factor of 0.45. Where information is otherwise lacking it is assumed that the original spacing was 2 m x 2 m. NAFP in the remarks column indicates data from the plots established in the Kathmandu Valley by the Nepal–Australia Forestry Project in the late 1970s, as recorded by M.R. Joshi and Wyatt-Smith (1982). Height and diameter measurements were only recorded from trees over 2 m in height. For calculation of mean heights and diameters it has been assumed that the unmeasured trees averaged 1.5 m in height by 2 cm in diameter, but for calculation of volumes it has been assumed that the volume of these trees was nil. The only species seriously affected by these assumptions were *P. roxburghii* and *P. wallichiana*. It is appreciated that the estimations of volume given are of doubtful accuracy, but they should be of some help in comparing growth rates of different species on different sites. It should be observed that the data are from very young stands, and that as the trees grow older the very large ratios between the growth of the fastest and the slowest species will diminish. This applies particularly to *P. roxburghii* and *P. wallichiana* which are particularly slow growing in youth. However the table does give some indication of how production can be increased by choice of the best species, at little extra cost apart from the cost of the seed.

Table 55—Comparative growth rates of various *Pinus* species in Nepal

Site	Altitude (m)	Species	Age (yr)	Survival (%)	Mean height (m)	Mean dbh (cm)	Estimated volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Remarks
Adabhar	250	<i>P. tecunumanii</i>	5.6	81	9.8	10.0	56	10.0	
		<i>P. caribaea</i> var. <i>hondurensis</i>	5.6	81	7.8	9.1	46	8.3	
		<i>P. oocarpa</i>	5.6	72	7.7	9.3	34	6.1	
		<i>P. caribaea</i> var. <i>bahamensis</i>	5.6	86	4.2	7.6	18	3.3	
Chitripani	480	<i>P. maximinoi</i>	7.8	63	13.0	15.1	165	21.1	
		<i>P. tecunumanii</i>	7.8	43	12.9	13.0	83	12.2	
		<i>P. elliotii</i>	7.8	98	7.6	9.8	63	8.1	
		<i>P. pseudostrobus</i>	7.8	92	7.9	9.1	53	6.8	
		<i>P. roxburghii</i>	7.8	92	6.1	7.5	28	3.6	
Trisuli	730	<i>P. kesiya</i>	6.0	89	6.7	9.0	34	5.7	
		<i>P. roxburghii</i>	6.0	94	2.7	5.4	7	1.2	
		<i>P. caribaea</i> var. <i>hondurensis</i>	6.0	27	4.6	6.0	3	0.6	NAFP plot
Syangja	1100	<i>P. greggii</i>	4.7	94	4.4	5.9	13	2.7	poor site
		<i>P. maximinoi</i>	4.7	83	4.2	5.4	9	1.9	
		<i>P. patula</i>	4.7	83	3.6	4.9	6	1.3	
Chautara	1500	<i>P. roxburghii</i>	9.0	80	8.7	11.4	52	5.8	vol. estimated from biomass

Table 55 cont.—Comparative growth rates of various *Pinus* species in Nepal

Site	Altitude (m)	Species	Age (yr)	Survival (%)	Mean height (m)	Mean dbh (cm)	Estimated volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Remarks
Godavari	1520	<i>P. caribaea</i> var. <i>hondurensis</i>	6.0	100	8.6	12.5	95	15.8	
		<i>P. kesiya</i>	6.0	88	8.2	11.3	67	11.2	NAFP plot
		<i>P. eliotii</i>	6.0	92	5.4	7.2	19	3.2	
		<i>P. roxburghii</i>	6.0	76	2.5	3.6	2	0.4	
		<i>P. patula</i>	7.0	92	9.5	11.1	78	11.2	NAFP plot
Lower Nagarkot	1700	<i>P. kesiya</i>	6.0	89	6.3	10.3	46	7.6	
		<i>P. caribaea</i>	6.0	97	5.5	8.3	29	4.8	
		<i>P. eliotii</i>	6.0	86	5.1	8.0	20	3.3	
		<i>P. roxburghii</i>	7.0	82	2.1	3.5	2	0.3	
		<i>P. wallichiana</i>	7.0	64	2.5	2.3	1	0.1	
Tistung	1900	<i>P. maximinoi</i>	6.8	100	11.2	10.8	115	17.0	
		<i>P. gregii</i>	5.6	96	7.9	11.0	91	16.3	measured vol.
		<i>P. patula</i>	6.8	81	9.8	10.4	76	11.2	
		<i>P. patula</i>	4.5	97	7.3	9.3	54	12.0	
		<i>P. pseudostrobus</i>	6.8	96	8.1	10.3	73	10.7	
		<i>P. kesiya</i>	6.8	81	7.9	10.7	65	9.5	
		<i>P. eliotii</i>	6.8	79	5.2	6.9	17	2.5	
			6.5	86	5.9	8.0	29	4.4	

Table 55 cont.—Comparative growth rates of various *Pinus* species in Nepal

Site	Altitude (m)	Species	Age (yr)	Survival (%)	Mean height (m)	Mean dbh (cm)	Estimated volume (m ³ ha ⁻¹)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Remarks
Tistung	1900	<i>P. densiflora</i>	6.8	83	3.5	7.5	14	2.1	
		<i>P. taeda</i>	6.8	77	4.2	6.4	12	1.7	
		<i>P. roxburghii</i>	6.8	94	4.0	5.6	10	1.5	
		<i>P. wallichiana</i>	6.8	48	2.5	3.1	1	0.1	
Pakhribas	1940	<i>P. maximinoi</i>	10.0	89	9.2	14.7	138	13.8	measured vol.
Upper Nagarkot	2000	<i>P. patula</i>	7.0	76	9.0	11.7	66	9.5	NAFP plot
		<i>P. kesiya</i>	6.0	100	6.9	9.8	42	7.0	
		<i>P. elliotii</i>	6.0	86	5.4	7.6	19	6.2	
		<i>P. caribaea</i>	6.0	79	4.1	5.7	8	1.3	
		var. <i>hondurensis</i>							
		<i>P. wallichiana</i>	7.0	91	3.2	3.6	3	0.4	
		<i>P. roxburghii</i>	7.0	92	1.8	3.6	2	0.3	

***Populus* L.**

Salicaceae

Poplar

Large trees. Leaves (in Nepal species) heart-shaped, 3–5-nerved at base. Male and female flowers nearly always on different trees, small, in pendulous catkins. Two species of poplar are native to Nepal, *Populus ciliata* and *P. jacquemontiana* var. *glauca*. In addition a number of exotic poplars have been introduced, of which clones of *P. deltoides* and its hybrid with *P. nigra* (*P. x canadensis* or *P. x euramericana*) are the most important.

Silvicultural characteristics

Poplars are deciduous, strongly light-demanding trees, often found naturally on alluvial land or near streams. Some are very fast growing. The seed is very small and light, and propagation from seed is rarely attempted except for research purposes and hybridization. Cultivated clones are of one sex only, and so propagation of these from seed is in any case impossible. Poplars are readily established by the use of cuttings. Most of them coppice and pollard well, and produce abundant root suckers.

Poplars are sensitive to day length; that is, many species and clones will not grow well unless there is an appreciable difference between the length of the shortest day in winter and the longest day in summer. This photoperiodic sensitivity has hindered the cultivation of poplars near the equator. In Nepal in midsummer the daylight lasts about 13.4 hours, and the shortest day is about 10.6 hours; fortunately this is sufficient to enable southern European cultivars of poplars to be grown, as can be seen in the poplar avenues of Kathmandu. Also cultivars which have succeeded in northern India are likely to be adapted to Nepal day lengths.

Poplars generally grow best in soils with a pH of between 5.5 and 7.5, on loamy soils, preferably with the water table within a few metres of the surface. Most will withstand temporary flooding but will not tolerate waterlogged soils with stagnant water. Fast-growing poplars have high demands for water. To obtain good results from poplars high-quality plants and good tending are essential.

Artificial regeneration

Poplars are always propagated from cuttings. Cuttings should be taken during the dormant season when the trees are leafless, in February. They may be taken from branches, epicormic shoots or root suckers, but should not be taken from

the crowns of older trees, as such cuttings may produce curved boles or a branchy habit. The trees from which cuttings are taken should be completely healthy, as any diseases present in the old trees will be carried on to their offspring. Care should be taken to select parent trees of good bole form and rapid growth.

The simplest method is take the cuttings from trees, and plant them directly where the trees are to be grown. This is the method used in the Muktinath Valley, Mustang, where cuttings approximately 25 cm long are planted, frequently in groups of three, as this is said to produce a larger, thicker trunk. When the branches reach the desired length of 3–6 m the trees are coppiced or pollarded. They are planted along canals (Pyers, 1985). In community forestry and other small nurseries in Nepal the practice has been to root cuttings in polythene bags filled with soil in February, and to plant them out in the monsoon in the same way as other plants raised in containers. This technique is simple, and for raising a few plants for use by farmers in the Middle Hills it may be the most practicable method, especially when irrigation is not possible.

However for raising poplars on a commercial scale more elaborate nursery techniques are needed; the following account is based mainly on Arendt and Lindgren (1990). Best results are from cuttings from one-year-old plants raised in the nursery in the previous year. The cuttings are taken between late January and the end of February, and should be well lignified, 15–20 cm long, with a mid-diameter of between 10 and 40 mm. The bottom end should be cut at an angle about one centimetre below, and the top end about one centimetre above, a bud; this is because the top end of the cutting is likely to dry out. The cutting should include 3–5 buds. If the cuttings are likely to remain more than an hour before being planted, as for instance during transport, the ends should be sealed with wax; for less than an hour this is unnecessary. The sealed ends should be removed before planting.

Directly after the cuttings have been prepared they should be soaked in water for 48 to 72 hours. After this they are first immersed in a fungicide (Emisan or Dithane M-45) and then an insecticide (Aldrin) for 30 minutes (Aldrin is a persistent organochloride, and should be used with great caution. It is banned in number of countries). They are then planted in nursery beds at 60 cm x 60 cm spacing, with their tops about level with the soil surface.

Nursery beds should be well manured; at Jogikuti near Butwal 20–25 t of farmyard manure ha⁻¹ are used. This manuring should be repeated each year. If farmyard manure is not available inorganic fertilizers can be used. In addition the application of 100 kg urea ha⁻¹, in two split doses in early May and early June, is recommended. The beds should be irrigated within six hours of the cuttings have been planted. Until the cuttings are well established irrigation

about twice a week will be needed; after this a seven- to ten-day watering interval, according to the weather and state of growth of the plants, will be enough until the onset of the monsoon.

Soon after sprouting, in April or May, shoots are singled to one per plant. The stems should be debudded by hand from the end of May to October to produce clean stems. Unsatisfactory stems should be culled. Thorough weeding, by hand, is essential for good growth, and should be done at least monthly; it can be discontinued after September. An alternative to weeding is the cultivation of crops between the poplar plants. Such crops should be short-lived and should not produce bulky masses of vegetation; tomatoes, chillies and gram (avoiding twining varieties) are suitable.

The plants are ready for planting after a year, when they should have reached a height of at least 3 m. They are planted as entire transplants. They are lifted carefully, avoiding damage to the roots; after lifting the roots should be trimmed to form a ball of a maximum diameter of 20 cm. All fine hair roots should be removed. The stems should be pruned by removing all branches and secondary sprouts. After lifting, the plants should be stored in fresh water, preferably under shade. The water should be changed frequently. Plants can be stored up to 2.5 months in this manner. In any case they should be soaked in water for at least 48 hours before transport to the field. (This nursery practice is suitable for the Terai, where commercial plantations of poplars are most likely to be attempted. In the Middle Hills longer periods in the nursery may be needed, and consideration might be given to the two-stage system proposed by Sharpe (1983a); see Napier and Robbins (1989). However it is doubtful whether the importance of poplar plantations in this region is likely to be great enough to justify such complicated and expensive nursery practises.)

Planting is in the dormant period, usually in January–February. The transplants are made into bundles of 25, with their roots wrapped in jute sacks soaked in water. During transport great care must be taken that the plants do not dry out. On arrival at the planting site they are again soaked in water for a further 2–4 days. Before planting the bottom metre of the transplant is dipped into a 0.25 per cent Aldrin emulsion (250 ml Aldrex 30EC in 100 l water) for 10 min, to protect against insects especially termites, and then into Emisan (250 g of Emisan-6 in 100 l water), to protect against fungi. In India the planting pits are prepared by a soil auger and are 22 cm in diameter by 1 m deep. The upper soil of the pit is mixed with 50 g single superphosphate and 5 ml Aldrex 30EC. For Nepal, Arendt and Lindgren (1990) recommend adding 2 kg of farmyard manure to each pit before planting, and to apply the Aldrin as 2 l of Aldrex emulsion (see previous paragraph). The soil is not compacted round the roots at

the time of planting, but after the first irrigation, which will cause the soil to settle, the pit is filled up to ground level, and then the soil compacted.

Planting in India is along irrigation channels spaced 5 m apart and the plants are spaced 4 m apart along the channels. This spacing can be varied to suit different crops, for instance. In the first and second years irrigation is needed every seven to ten days from the time of planting until the onset of the monsoon, twice a month from October to January or February, and from March to the monsoon every 7–10 days. Thereafter a minimum of two irrigations per month during the hot season, and one per month during the winter post-monsoon season, will be needed. The duration of irrigation may be reduced if there is a permanent water table near the surface. During irrigation care should be taken not to cause waterlogging.

Intercropping, involving weeding and soil working, is essential for good growth of poplars; the alternative is manual clean weeding, which can usually be ruled out because of its cost. A number of crops can be used, depending on farmers' needs, though maize is undesirable as it is the host of a disease which affects poplars, and paddy because it grows in standing water. Tall perennial herbs, such as palmarosa and lemongrass, which compete with the trees for water and nutrients should be avoided during the early life of the plantation. Summer crops include peanuts, sesame, pigeon peas and tomatoes for the first three years, and later, when the canopy has closed, such crops as turmeric and ginger; during winter, when the trees are leafless, a wider range can be grown including wheat, barley, oats, potatoes, sweet potatoes, sugar cane, and many other vegetables. Mint (*Mentha arvensis*), a perennial, has been used successfully at the Medicinal Herbs Farm, Tamaghari, Bara District (Adkins, 1988). Sometimes however there are conflicts between the needs of the crops and the trees; farmers do not irrigate ripening wheat, for instance. Fertilizer may be needed for the crops; if so the trees will benefit as well.

To produce high quality timber for veneers, including matches, the stems must be pruned. Immediately after sprouting the lower third of the stem should be debudded. In the first dormant season double leaders should be removed, and beginning in the second dormant season side branches should be removed by cutting them off flush with the bole, up to a third of the total height of the tree. From the end of the third year pruning can extend to half the total tree height, and should be continued until a total height of 8 m has been pruned. Normally pruning will not be needed after five years. Poplars are planted at the final spacing, and no thinning should be needed.

Growth and yield

In some countries hybrid poplar plantations produce very high annual yields, up to $40 \text{ m}^3 \text{ ha}^{-1}$, and give economic returns comparable with, or even higher than, agricultural crops. To obtain this sort of yield and return the plantations must be on fertile soils, and high inputs are needed, including irrigation in Nepal. In Uttar Pradesh, in India, poplars grown for match production are expected to produce a mean annual increment, on an eight-year rotation, of about $20 \text{ m}^3 \text{ ha}^{-1}$ under bark.

Pests and diseases

Cultivated poplars are subject to attacks by numerous pests and diseases (FAO, 1979) but fortunately nothing serious has yet appeared in Nepal, apart from defoliation of avenue trees by insect larvae. A close watch should, however, be kept for outbreaks of pests or diseases.

Uses

Poplars produce a white, soft, even-grained timber, which is not durable. In industrial countries it is used for boxes, shelving, and other purposes for which strength and durability are not important. Much of it is made into veneer, used both for plywood and matches; it is one of the best match woods. It is also used for paper pulp. In some arid countries (Syria, Iraq, Afghanistan), and in the Muktinath region of Mustang, Nepal, the poles are used for house building. It is not a good fuelwood, as it is light in weight (300 to 450 kg m^{-3}) and has a relative low calorific value, about $19,500 \text{ kJ kg}^{-1}$. It is somewhat difficult to ignite and tends to smoulder rather than to burn with a clear flame. It is used as fuel in some countries, but generally where no better fuelwood is available. The leaves are used for fodder in some countries including parts of Europe. The crude protein content on a dry-matter basis is about 15 per cent (FAO, 1979).

Importance in Nepal

The indigenous poplars have not been planted on a large scale, and little information is available on their performance in plantations. They, together with willows, are among the most important trees in the arid Mustang region. In the Middle Hills exotic poplar clones have grown very well in places as avenue trees, but results in conventional plantations have generally been poor, probably from a combination of poor soil, inadequate water supplies, and lack of care. In a few places, for instance in parts of Solokhumbu District, farmers have planted a few trees near their houses and along irrigation channels, with some success. However for practical purposes large-scale poplar plantations can be ruled out for this area.

In the Terai prospects for poplar growing, under irrigation, are much better, as has been shown under similar conditions in Uttar Pradesh in India. Raising poplar plants in nurseries requires a good deal of care and expertise, certainly beyond the capabilities of a semi-skilled nursery naike, so specialized nurseries would be needed. However from these nurseries plants could be provided to farmers; technical advice would also be needed.

In India the match company Wimco supplies plants to farmers and guarantees to buy back the trees, when they have reached 90 cm girth, at a fixed price. Farmers are also given help in getting loans. Ninety-five per cent of the plantations are in blocks of between one and five hectares, and most of the rest are in lines along field bunds, or as avenues. Similar schemes could be tried in Nepal.

General references: *Poplars and willows* (FAO, 1979) covers all aspects of poplar cultivation, though with more emphasis on temperate regions. The older version of this publication (FAO, 1958) contains some information not included in the second edition and is still worth consulting. For cultivation in Nepal see Arendt and Lindgren (1990); Lindgren (1987); Napier and Robbins (1989); United States Forest Service (1976); Viart (1987). Cultivation of poplars in Uttar Pradesh, India, is described in N. Jones and Lal (1989) and Napier (1987a).

***Populus ciliata* Wall. ex Royle**

Nepali: bange kath (bangikot).

Leaf buds sticky. Leaves 10–17 cm by 7–12 cm, usually deeply cordate at base; margins finely crenate-serrate, with short hairs along them. In Nepal it is found mostly from 2000 m to a little above 3000 m, though in the western Himalaya it descends to 1200 m. It is commonest in western Nepal, where it is usually found in moist habitats near streams. Its natural range extends from Kashmir to Burma. It may be the poplar grown under irrigation in Mustang, but this needs to be confirmed by specimens. It is more tolerant to unfavourable soil conditions than the exotic poplars, and is capable of growing on dry hillsides, though there it does not grow to a large size. Best growth is obtained on well-aerated, loamy soil with abundant moisture. It does not coppice well, except when the trees are young, but pollards well and produces very numerous root suckers. Young seedlings and saplings are killed even by light fires; older trees will survive light ground fires, but are killed by crown fires. Its wood weighs about 450 kg m⁻³, and would be suitable for planking, etc., and probably matches. The leaves are used for fodder, especially for goats, but generally only in times of

scarcity. The bark is used as a tonic, stimulant and blood purifier. The tree is under trial for soil stabilization on slopes in India (H.N. Mathur *et al.*, 1982). *Populus ciliata* can be raised from seed, though with some difficulty (for the techniques see Troup, 1921). The normal way of propagating it is by cuttings, using the general techniques for poplars. The statement that poplars of the section *Leucoides*, to which *P. ciliata* belongs, cannot easily be propagated by cuttings (FAO, 1979) is incorrect in this case. Growth is fairly rapid, and rooted cuttings should increase in height by 1–1.5 m during the year after planting. Ring counts of older trees in India have shown a mean annual diameter increment of between 6 and 9 mm.

References: Anon. (1981c); M.W. Campbell (1983a); Deol and Koslar (1983a; 1983b); Gamble (1922); H.N. Mathur *et al.* (1982); R.V. Singh and Kashyap (1982); R.V. Singh and Sharma (1984); Suri and Seth (1959); Troup (1921).

Populus jacquemontiana Dode var. *glauca* (Haines) Kimura

(Syn. *P. glauca* Haines)

This has sticky buds, angular shoots, and long-petioled leaves which are grey-green above and bluish-green beneath, and which flutter in the wind. It differs from *P. ciliata* in having larger leaves (18–25 cm by 15–20 cm), with more sharply toothed margins. It is found in eastern Nepal between 2600 and 3000 m. In northern Bengal, India, it is known in Nepali as pipal pate or dude malata (Cowan and Cowan, 1929). As far as is known it has not been planted.

Exotic poplars

Nepali: lahare pipal.

A number of exotic species are recorded as having been introduced to Nepal, but with the exception of *P. nigra* cv. 'Italica', q.v., the only cultivars known to survive are clones of *P. deltoides* Marsh. or its hybrids with *P. nigra* L. These are commonly known among poplar specialists as *P. x euramericana* (Dode) Guinier, but botanically are more correctly called *P. x canadensis* Moench, despite this being a misleading name as the hybrid originated in Europe, not Canada. However the name *P. x euramericana* will be used with numbered cultivars, as is the general custom. The botanical distinction between *P. deltoides* and its hybrid is difficult. *Populus deltoides* has ciliate leaf margins, and two small glands at the junction of the leaf stalk and the blade, whereas in *P. x canadensis* the leaf margins are hairless or very sparsely ciliate, and the glands are often absent. To avoid confusion the cultivar name or number should be cited.

Populus deltoides and its hybrids

One of the cultivars first introduced into Nepal is *P. x euramericana* cv. I-214, originally raised in Italy (as indicated by the I) and planted throughout the world in areas of suitable climate since the 1940s. This is represented by the trees round the Department of Forest, Babar Mahal, Kathmandu, and along some of the avenues in Kathmandu. It was introduced into Nepal in 1965 from Pakistan by E.J.B. Rana and K.B. Chitrakar. It is a female clone which is capable of very rapid growth, as is shown by the Kathmandu trees. One drawback is its tendency to produce heavy branches, and to obtain good quality timber careful and regular pruning is essential. It has been successfully planted as an avenue tree in a number of localities in Nepal, but so far plantations in blocks have been unsuccessful.

Other early introductions were *P. x euramericana* cv. D- 65/27, *P. deltoides* cv. IC and *P. delioides* cv. D-61 introduced from India, and planted near Chalnakhel nursery, by the Nepal–Australia Forestry Project in 1977 (Nepal–Australia Forestry Project, 1980). About 9.5 years after planting five out of 19 (26 per cent) of D-65/27 and two of the combined total of 39 plants (five per cent) of the two clones of *P. deltoides* had survived. Growth of D-65/27 was quite good considering the neglected state of the plot, averaging about 15 m in height by 14.5 cm dbh, despite severe leaf necrosis having been recorded in the year after planting (Viart, 1987). This clone, like all D-cultivars, originated from the USDA Southern Forest Experiment Station, Stoneville, Mississippi.

In March 1984 two clones of *P. deltoides*, G-3 and G-48, were planted at Sagarnath by the Sagarnath Forestry Development Project. They were imported from Haldwani in India, but both originate from Grafton, New South Wales, Australia (hence the G-number). At the site the water table is within 3 m of the surface. The plots were irrigated once weekly until the onset of the first monsoon, and intercropped with vegetables during the first year. They were weeded to control *Eupatorium* in August of the first year and June of the second year. The plots were visited by Viart in January 1987. Growth was very variable. G-3 ranged in height from 5–7 m to 10.5 m and G-48 from 3–5 m to 13.2 m. Measurements of two rows of each clone gave a mean dbh of 7.3 cm for G-3 and 5.7 cm for G-48. The maximum dbh of G3 was 10.8 cm, and of G8 11.5 cm, with 92 per cent and 85 per cent survival respectively. Viart considered these results neither good or bad. He had doubts about the clonal purity of the material.

A trial of a number of clones was planted by the Butwal Plywood Factory in 1986 in the nursery at Jogikuti, near Butwal. The following results (Table 56) were obtained from plants still in the nursery, one year after first planting

(Lindgren, 1987). Judging by these early results best results were from 65/27, D-82 and D-121. 65/27 probably is the result of hybridization between a fastigiate cultivar of *P. nigra* and a selected *P. deltoides* from Stoneville. It is evergreen and considered most suitable for fuel, pulp and fodder. *Populus deltoides* D-67 has been given the name of *P. deltoides* cv. Mississippi Slim. Other clones recommended for the Terai are 69/55 from America and L39, a hybrid of G3 and G48 (Arendt and Lindgren, 1990).

Table 56—Survival and growth of clones of *Populus deltoides* at Jogikuti

Clone	Survival (%)	Height (m)	dbh (cm)	Disease	Stem form	Branches per tree
<i>P. deltoides</i>						
D-67	97.1	4.8	2.8	2	3.0	5.7
D-82	76.5	5.1	3.0	1	5.0	5.7
D-121	86.7	5.2	2.9	1.5	4.7	8.8
D-181	73.9	3.3	1.8	5	1.5	7.5
G-3	68.4	4.8	2.7	4	3.0	20.4
G-48	78.0	4.7	2.5	4	3.0	20.7
S7/C-1	70.3	4.9	2.6	3	3.0	22.6
S7/C-4	50.0	5.4	3.1	2	3.7	13.3
S7/C-8	47.3	5.5	3.0	2	3.5	10.9
S7/C-15	86.7	4.2	2.2	3.5	2.0	10.1
S7/C-20	76.5	5.1	2.5	3	3.5	14.8
<i>P. x euramericana</i>						
65/27	97.1	5.6	2.6	1.5	4.5	11.2

Notes: Diseases: 1 nil, 5 much; stem form: 1 bad, 5 good; branches per tree after five months.

A poplar introduced as *P. monilifera* Ait was planted near Jiri, Dolakha District (Stebler, 1970), and later along the Jiri-Lamosangu Road. It was said to have outgrown both *P. x euramericana* cv. I-214 and *P. ciliata*; on the Jiri-Lamosangu Road it reached 3 m in height in three years. The exact identity of this poplar is doubtful. *Populus monilifera* is usually taken to be a synonym of *P. deltoides*, and presumably this poplar is a *P. deltoides* clone which is particularly adapted to cold conditions (Jiri is 2000 m, and has an average of 44 days

of frost a year). It would be interesting to try to rediscover it. In 1986 a poplar said to come originally from Jiri was being planted near Salleri in Solokhumbu, and was gradually being spread eastwards by villagers; it could perhaps be this clone.

Populus deltoides cv. Harvard (63/51) and cv. Lux (69/55) were introduced to the Trisuli watershed in 1968, and showed moderate early growth. The same two clones were being propagated in Chalnakhel nursery in 1987, together with cv. G-48 (Viart, 1987), but growth was poor. No recent information on growth in plantations has been seen.

Populus deltoides cvs. D-01, D-25 and D-75 were planted at Nisikot, Dhad-ing District, on poor soil at an altitude of 1400 m. Growth of all was poor, with heights of 50–60 cm at 2.3 years old. Obviously a site unsuitable for poplars, but unfortunately typical of many where poplars have been planted in the Middle Hills (S. Rimal, 1992).

***Populus nigra* L. cv. Italica**

Lombardy poplar.

This was probably introduced many years ago. This ornamental tree is widely planted in avenues in Europe, and has been used successfully as an avenue tree in Kathmandu. It has a very narrow crown of branches ascending almost parallel to the stem; because of this branching habit the wood tends to be knotty and generally unsuitable for timber. In Kashmir the leaves are valued for fodder, and are readily eaten by cattle (FAO, 1979).

Miscellaneous species and cultivars

The following have been introduced, mostly in Sikaurichaur in the Trisuli watershed about 1968. Little more is known about them, but some of them may turn up. *Populus alba* L. cv. I-58/57 and also a clone from China; *P. alba* x *tremuloides* cv. I-056/67, and I-17/60 (both unsuccessful); *P. alba* x *grandidentata* cv. I-5A/62; *P. angulata* x *simonii* cv. I-026/67 and I-027/67; *P. cathayana* x ? I-012/67 ; *P. lasiocarpa* Oliv. (from China); *P. nigra* cv. TR-56/52, and TR-56/75 (from Turkey via Pakistan); and *P. trichocarpa* cv. I-043/67.

***Prosopis* L.**

Mimosaceae

Trees with bipinnate leaves, usually with spines. Flowers in cylindrical spikes; stamens ten.

***Prosopis juliflora* DC**

Mesquite.

A small, thorny, American tree, not planted very much so far in Nepal, but a possible species for dry calcareous (usar) sites, in the lowlands. It is tolerant of very arid conditions. The leaves are unpalatable, and hence the tree is resistant to browsing. The pods are, however, an excellent fodder and are produced in profusion. Animals after eating the pods disseminate the seed in their dung, and so in certain circumstances the plant can be an invasive weed; for this reason it should be avoided on or near agricultural land. In northern India the seed ripens in May and June. It can be sown directly into polypots, and the seedlings will be ready for planting out in the monsoon. The seed has a hard coat and scarification may be needed. In addition to the use of the pods as fodder the wood is an excellent fuel and makes first quality charcoal. Much of the *P. juliflora* planted may in fact be other species, especially *P. glandulosa* Torrey. Other species of mesquite worth trial on difficult alkaline sites include *P. chilensis* (Molina) Stutz, from the arid west coast of South America, and *P. tamarugo* F. Philippi from Chile. These two species are not as aggressive as *P. juliflora*, and are less likely to become harmful weeds.

References: Habit *et al.* (1981); National Academy of Sciences (1979); Troup (1921). For taxonomy see Burkart (1976).

***Prunus* L.**

Rosaceae

Trees or shrubs. Leaf margins usually finely toothed; leaves usually with sessile glands near apex of stalk. Flowers in axillary racemes or fascicles. Calyx lobes five, petals five, deciduous; stamens ten to many. Fruit a drupe with a hard one-seeded stone.

***Prunus cerasoides* D. Don**

(Syn. *P. puddum* Roxb. ex Brandis)

Nepali: painyu (paingyo, paiyun); ban paiyun.

Tree up to 15 m tall. Leaves ovate or oblong-elliptic, 5–12 cm by 3–4 cm, shortly acuminate, margins finely serrate, 2–5 small glands at apex of leaf stalk. Flowers 1–3 together, on stalks 1–2 cm long, unfolding with the young leaves; petals pink. Fruit ellipsoid, 1–1.3 cm by 0.5 cm, yellow and red.

Occurrence

It is found in most parts of Nepal between 1300 and 2400 m. Outside Nepal it extends from the Punjab in the west to China in the east.

Silvicultural characteristics

A medium-sized tree, reported to stand a certain amount of shade, especially when young. Its altitudinal distribution indicates that certain provenances at least are frost-tolerant, but when planted on an exposed south-facing slope at 1900 m at Pakhribas 90 per cent of the plants had their tops killed, presumably by cold, though only six per cent were completely killed. Seedlings with the top damaged by cold will usually recover. Frost damage has also been recorded in nurseries. It is more tolerant of poor soil conditions than most species except pines, and has survived well on nearly all sites where it has been planted. It reproduces fairly freely from root suckers, and is said to coppice. The seeds are spread by birds.

Artificial regeneration

The seed ripens between March (Pokhara) to May (many sites). The fruit is red when ripe and contains a single stone. About 1700 fruit weigh 1 kg, and there are 2500–3200 cleaned seeds kg⁻¹. After collection, the pulp should be removed from the seed and the seed dried thoroughly in the sun for at least 2–3 days. Seed stored in cloth bags loses its viability rapidly, but in plastic bags under nursery conditions it can be stored for nine months without serious loss of viability; in fact in experiments reported by Napier and Robbins (1987) percentage germination increased from 74 per cent at the start of the experiment to 93 per cent after three months; at 12 months it had fallen to 63 per cent and after 15 months it was nil. Seed stored in sealed glass jars in a refrigerator still gave over 90 per cent germination after 12 months, and 85 per cent after 15 months. Thus if seed has to be stored for longer than nine months refrigerated storage is preferable.

Before the seed is sown it should be soaked in water for 1–2 days. Below 1500 m seed sown immediately after collection in March or April should give plantable seedlings by the monsoon (seed sown in Chalnakhel (1350 m) in October produced plants over 30 cm high by July, despite top pruning). Above 1500 m seed should be sown in late August to early September, giving 10–11 months in the nursery. Plantable seedlings should be 20–30 cm tall, with a root-collar diameter of at least 2 mm, and well-lignified stems. If the seed is fresh, or is known to have a germination percentage of over sixty, it should be sown directly into standard polypots filled with a mixture of three parts soil to one of sand, at two seeds per pot. If the germination percentage is less than this the seed should be sown in beds, at the rate of 750 g m⁻², and the seedlings pricked out into pots within 2–3 weeks after the start of germination, preferably after two primary leaves have developed above the cotyledons. Early growth of the seedlings is very rapid, so this pricking out must not be delayed. Shade is needed only for 3–4 days after pricking out, and in cloudy weather may be dispensed with.

Germination is usually fairly rapid, taking between 12 days and three weeks, but at Chalnakhel between six and 11 weeks has been recorded. The germination percentage is usually quite good. The number of plants raised from 1 kg of seeds in Nepal nurseries has ranged from 300 to 3000, the median figure being about 1200.

Seedlings from sowings in August–September lose their leaves in October–November, and are not damaged by winter frost. Growth after winter is very rapid, so that the seedlings tend to become tall and thin, with soft stems. They should therefore be spaced out with 5–10 cm between the rows in March (for sowings in August–September) or May (for spring sowings). Root pruning must also be done in spring, and continued as required. If the seedlings are over 30 cm tall in the pre-monsoon or early monsoon period they should be cut back to 15–20 cm two weeks before the expected planting date. The seedlings develop thin taproots, with some fibrous lateral roots.

Some successes have been reported from bare-root planting. Grunenfelder (1980a) in the IHDP project in the Charikot-Jiri area recommended broadcasting the stones in nursery beds in May, and planting out the seedlings bare-root in July of the same year. Seedlings supplied to farmers, however, were first pricked out into plastic bags. Branney (1985) describes how bare-root plants were used at Jajarkot. The seed was sown into beds in April, and the plants kept under shade until early June. By mid-July the seedlings averaged 5 cm tall, and there were about 400 m⁻². These seedlings were transplanted directly into pits in the plantation, and six months after planting 98 per cent had survived. It should be noted that in this trial conditions were near optimum. The nursery was very

near the planting site, and a good rainy spell followed planting. Wilson (1987) reported good results in Darchula, in the Far Western Development Region of Nepal, from bare-root plants 120–150 cm tall; they sometimes died back after planting but shot again from the base, leading her to suggest the possibility of using stumps. According to Troup (1921) propagation by cuttings is also possible.

Some trials have been made of the use of fertilizers on *P. cerasoides*. The following table (Table 57) summarizes the results. *Prunus cerasoides* appears to benefit by being planted under light shade of pines. In most cases survival and height growth has been better under light shade than in the open. Some trials have also been made on larger pit size (Table 58).

Table 57—Fertilizer trials on *Prunus cerasoides*

Site	Age (yr)	Fertilizer	Survival (%)	Mean height (cm)	Remarks
Tistung	2.3	Nil	100	66	
		25 g Complexol	98	111	
		50 g Complexol	96	131	
		Compost	98	107	
	4.4	Nil	96	95	Same trial as above
		25 g Complexol	96	144	
		50 g Complexol	96	174	
		Compost	96	134	
Thulo Sirubari	3.5	Nil	96	150	From Shakya (1991)
		25 g NPK	97	180	
		50 g NPK	93	190	
		Compost	97	180	
Irkhu	2.4	Nil	—	81	In shade three-year-old pine
		50 g Complexol	—	127	
Sangachowk	2.4	Nil	78	80	In shade four-year-old pine
		50 g Complexol	93	209	
Melechaur	2.4	Nil	—	45	In shade ten-year-old pine
		50 g Complexol	—	61	

Notes: Complexol is a 20:20:0 artificial fertilizer. Compost consisted of half a *pathi* (4.5 l) of farm compost. All rates per tree.

Table 58—Growth of *Prunus cerasoides* in different sized pits

Site	Age (yr)	Pit size (cm)	Survival (%)	Mean height (cm)	Source
Tistung (1950 m)	1.5	15 x 15	79	40	Shakya (1991)
		30 x 30	92	70	
		45 x 45	94	110	
		50 x 50	98	110	
Namdu, Dolakha (1360 m)	2.0	30 x 30 x 30	44	42	Neville (1987c)
		100 x 100 x 100	53	86	

The measurements for Tistung are for cylindrical pits, those for Namdu for cubes. At Tistung pits smaller than the standard 30 cm x 30 cm pit reduced survival and growth, while the larger pits increased growth but not survival. The very large pits at Namdu, which cost 40 times as much as the standard pits, increased height growth from very poor to moderate, and also survival, but this remained very poor.

Performance in plantations and rate of growth

Data are only available from plantations less than five years old, except an old record from the Nepal–Australia Forestry Project at Upper Nagarkot (2000 m) where, at the age of seven years survival was 92 per cent, of which 73 per cent were over 2 m high, and these averaged 2.2 cm in diameter (M.R. Joshi and Wyatt-Smith, 1982); and one from Parbat District, near Lumle, at an altitude of 1800 m, aged seven years, survival 86 per cent, and mean height 1.3 m (R.K. Shrestha and Gautam, 1991), which is poor.

In general survival in trials has been good, over 80 per cent, with a few exceptions. An average figure for mean height would be about 1 m at two years. Among the best height growths from unfertilized plantations in the open are 1.75 m at 2.4 years at Banduk, Myagdi District (1450 m) (R.B. Joshi, 1985); 1.6 m at 2.2 years on a poor site with northerly aspect at Nisikot, Dhading District (1400 m) (S. Rimal, 1992), and 2.8 m at four years at 1800 m in Parbat District (R.K. Shrestha and Gautam, 1991). Compared with many fodder species early height growth is quite good, but it apparently slows down later, as the tree does not grow to a great height.

Uses

It is a fodder tree, but of somewhat limited value. According to Panday (1982) it is used mainly as fodder for sheep and goats, not cattle; however in Solokhumbu although cattle find it unpalatable they will get used to it if no other fodder is available. It is said to cause urinary problems and reduce milk yields. The smaller branches are 'used as a substitute for hydrocyanic acid' (Department of Medicinal Plants, 1970), and poisoning of sheep by the hydrocyanic acid produced by *P. cerasoides* leaves has been recorded. The tannin content of the leaves rises from rather low levels in December to moderately high levels in March (Wood *et al.*, 1992). The leaves contain 6.4 per cent crude protein (Panday, 1982); 10.4 per cent (D. Bajracharya *et al.*, 1985).

The old leaves fall between mid-October and mid-November, and the flush of new leaves follows soon after. The trees are lopped in June and July when the leaves are mature and have been washed by rain. According to Panday one tree will yield 80–120 kg of fresh fodder per year, but other sources give much lower values.

The wood weighs 720 kg m⁻³ and has a calorific value of 19,100 kJ kg⁻¹ (Hawkins, 1982). In addition to its use for fuel it is also valued as a small construction timber. Walking sticks are also made of it. The ripe fruits are edible and the seeds are used in necklaces. It has been widely planted around Kathmandu as an avenue tree.

Importance in Nepal

Its use as fodder is generally on rather a small scale. In the villages studied by Upadhyay (1991) it was used as fodder to a small extent from farm and fallow land in Dhading District in the Middle Hills; there it was valued mainly as a multipurpose species. It was not used at lower altitudes. In Dolakha District it formed about eight per cent of farmers' trees (Robinson and Neupane, 1988), and in the Lumle Extension Command Area about four per cent. It was used to a small extent by the farmers in Lalitpur studied by Upton (1990).

In the parts of Sindhupalchok and Kabhrepalanchok Districts studied by Carter and Gilmour (1989), at higher altitudes (Nalla, 1774 m, and Devitar, 1405 m) it was the most common tree found on cultivation terraces. At Nalla, where it formed 39 per cent of trees found, farmers had planted their terrace edges with seedlings dug out from forest areas, and were tending them well. The main reason for planting *P. cerasoides* appeared to be that it can be propagated easily; it is more prized for construction and fuel than for fodder. Below 1200 m it was little used.

Prunus cerasioides has also been widely raised in community forestry nurseries. It has had high survival rates on many sites, at altitudes ranging from 500

to 2000 m. For a hardwood in the Middle Hills its early growth rate is relatively rapid. This combination of ease of establishment and relatively good growth are the main points in its favour.

References: M.W. Campbell (1983a); Gamble (1922); Grunenfelder (1980a); Kessler (1981); Lamichhaney and Joshi (1980); Napier and Robbins (1989); Rao and Purkayastha (1972); Streets (1962); Troup (1921).

***Prunus napaulensis* (Seringe) Steud.**

(Syn. *P. nepalensis* auct.)

Nepali: aru pate, jangali aru.

Leaves 6–18 cm by 1.5–5 cm, finely toothed, stalks 0.5–1 cm long. Flowers white, in more or less erect spikes. Found in Nepal at 1500 to 3200 m. It is recommended by M.W. Campbell (1983a) as a good, hardy afforestation species for timber and fuelwood. It is fairly tolerant to frost, but when planted at Pakhribas on an exposed slope at 1900 m, 20 per cent of the seedlings were killed, and a further 30 per cent had the tops killed back. The fruit ripens between October and December, and there are about 1400 seeds kg⁻¹. The viability of the seed is about six months, but more than 80 per cent germination has been obtained from five-month-old seed. The wood weighs about 650 kg m⁻³. The tree reaches a height of about 2.7 m in five years (Suri and Seth, 1959).

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Rao and Purkayastha (1972); Suri and Seth (1959); Troup (1921).

Note: The name aru pate in Nepali is also used for *Prunus cornuta* (Wall. ex Royle) Steud. (*P. padus* auct. non L.) which according to Bhandary and Shrestha (1984) occurs in Kathmandu Valley and is poisonous to cattle. It differs from *P. napaulensis* in having drooping, rather than erect racemes, and small tufts of hairs in the axils of the leaf veins. There are about seven other species of *Prunus* native to Nepal, and in addition the apricot (*P. armeniaca* L., Nepali: khurpani), the peach (*P. persica* (L.) Batsch, Nepali: aru), the plum (*P. domestica* L., Nepali: alubukhara, the cherry plum (*P. cerasifera* Ehrh.), the cherry (*P. avium* (L.) L.), and the almond (*P. dulcis* (Miller) D.A. Webb, Nepali: kagaji badam) are cultivated for their fruits.

Pyrus L.

Rosaceae

Deciduous trees. Leaves simple. Flowers usually showy; petals five, free. Fruit fleshy, containing several seeds at centre.

Pyrus pashia Buch.-Ham. ex D. Don

Nepali: mayal, mel.

A small to medium tree, often spiny. Leaves long-pointed, toothed, quite hairless, shining. Flowers 2–2.4 cm across, white, in axillary clusters. Fruit globular, 1.3–2.5 cm, dark brown. Found between 1450 and 2500 m. It is common in the heavily settled Middle Hills, where it is conspicuous in spring from its white flowers. The fruits ripen between November and January, when they turn blackish and begin to rot, and the seed may be extracted. There are between 70,000 and 110,000 seeds kg⁻¹. The seed is said to lose its viability quickly once extracted from the fruit, but large fresh seed will give about 75 per cent germination. Seed sown when collected will give plantable stock by the next monsoon. *Pyrus pashia* can also be easily raised from hardwood cuttings. Its wood is light reddish-brown, hard and close-grained. In India it is used for walking sticks, combs and other small articles. It weighs about 700 kg m⁻³ and is a good fuel. The fruit is edible but astringent, and is usually eaten when half rotten, like the medlar. It is not much used as fodder; according to R.V. Singh (1982) the fodder in India is eaten only by sheep and goats. It is a promising species for live hedges, and according to Troup (1921) is useful in preventing landslips, as it has spreading superficial roots and produces abundant root suckers.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Rao and Purkayastha (1972); Troup (1921).

Pyrus communis L.

Pear.

Nepali: naspati.

A widely cultivated fruit tree which differs from *P. pashia* in its broader leaves and larger fruit, with the calyx lobes persistent beneath the fruit. The form most commonly grown near Kathmandu has an almost globular fruit with a russet skin.

Quercus L. and *Lithocarpus* Blume

Fagaceae

Oak

Older botanists included *Lithocarpus* in the genus *Quercus*, but it is now usual to consider them as separate genera. One distinction is that the fruit in Nepalese species of *Lithocarpus* occurs in clusters with the cups holding the seed coalescing together, while the fruits of *Quercus* are separate from each other. Oaks are a dominant feature of the vegetation in many parts of Nepal, particularly between 2000 and 3000 m, and are a very important source of fuel, timber and fodder.

Regeneration

The fruit of oaks is called an acorn, and consists of a single seed held in a cupule or small cup, which according to the species may almost completely enclose the seed or merely cover the base of it. Most oaks ripen their seeds after the end of the rainy season, between October and January (an exception is *Quercus semecarpifolia*, in which the seeds ripen in the middle of the rains, in July or August). In nature the seed remains on the ground during the winter, and germinates during the next monsoon. The seed of many species, especially those from higher altitudes, need a period of cold to promote germination, and if they are sown in nurseries in October to December they will not germinate until March or April of the next year.

Oak seed is recalcitrant, and if stored must be kept moist. Seed of *Q. semecarpifolia*, which ripens in summer, cannot be stored at all and must be sown within 2–3 days after collection. Seed of others can be stored for 4–5 months over winter if kept moist, cool and aerated. The seed should be kept under shade at all times and never dried in the sun. To store seeds they should be mixed with 2–4 times their volume of damp sand and put in a fine wire mesh bag, or a closed clay pot, and buried in a pit 1–1.5 m deep. If refrigeration is available moist storage at about 4°C can be used. Cold stratification over winter can be obtained in practice by sowing the seed in the autumn, immediately after collection, and allowing it to remain in the nursery beds over winter, taking care to protect it against rodents; or by storing it in pits, as described above. Refrigerated storage will have the same effect.

The simplest nursery technique for raising oaks is to sow the seed directly into polypots, at the rate of one per pot. Large pots should be used, at least 4 inch x 7 inch (12 cm x 18 cm), when filled. A good potting mixture should be used, containing 20–25 per cent compost. The seed should be sown on its side

and covered with about 5 mm of fine soil. During hot weather the seedlings may need to be shaded for several weeks after germination.

An alternative method is to sow the seed in beds in lines 5 cm apart with 3 cm between the seeds, and later prick out the seedlings into polypots. This needs considerable care as germination is hypogeal—cotyledons emerge from the seed below ground level—and meanwhile the seedlings rapidly develop large thick radicles, which may reach 8–12 cm long before the plumule, the embryonic shoot, appears above the level of the soil. Thus if seed is sown in beds the seedlings should be pricked out into pots as soon as the plumules of a few of them have emerged. After pricking out the germinating seed, or cotyledons, should be just below the soil surface. The pots with the newly pricked-out seedlings should be shaded until the onset of the monsoon.

Germination of seed sown in spring usually begins after 4–8 weeks. If the seed is well stratified the germination percentage is usually high. Because of the very strong taproot regular and frequent root pruning is essential, otherwise the seedlings will die when they are lifted for planting out. This pruning should begin during the first monsoon. Oaks are slow growing in the nursery and seedlings from seed sown in spring will need 15–16 months before they can be planted in the field; at altitudes over 1800 m another year will be needed. The use of bare-rooted seedlings has generally given poor results, but in Darchula District, it is said to be possible provided that altitude is above 1500 m and the planting site is less than 1.5 hours walk from the nursery. Because of the difficulties of raising oak seedlings in nurseries, in India direct sowing was at one time used on a large scale, but in addition to other disadvantages the seed is very liable to be removed and eaten by rodents. However if abundant seed is available it would be worth making more trials of this method in Nepal. Dibbling in seeds could be used to fill gaps in communal forests. Early growth of oaks tends to be slow.

Uses

The timber is not usually the most valued in any locality, but is used for rough building work. The fuelwood is of high quality, and produces good charcoal. As fodder trees oaks are valued not so much for the quality of the fodder, which is only medium, but because of their abundance in many parts of Nepal. In many places, especially at altitudes over 2000 m, they are by far the most important source of tree fodder. In Nepal up to the present oaks have only been planted on a small scale. Indeed a more pressing problem is the protection and rehabilitation of very large areas of heavily coppiced and over-lopped areas of natural oak forest. Volume and biomass tables and equations for oaks have been published by E.R. Sharma and Pukkala (1990a; 1990b).

Key to *Quercus* and *Lithocarpus*

- (1) Cups of acorns (in Nepal species) fused at base; margins of leaves not toothed 2 (*Lithocarpus*)
- (1) Cups of acorns not fused 3 (*Quercus*)
- (2) Cup covering lower third of acorn only; acorn shining *L. elegans*
- (2) Cup almost completely covering acorn, except for tip *L. pachyphylla*
- (3) Scales of cup fused into concentric rings surrounding acorn 4
- (3) Scales of cups not fused into concentric rings 7
- (4) Cup 4–7 cm in diameter, enclosing all but apex of acorn; Leaves over 15 cm long, dark green *Q. lamellosa*
- (4) Cup less than 3 cm in diameter 5
- (5) Cup enclosing more than half of acorn, with tawny hairs; acorn depressed globular; leaves 10–20 cm long; rare tree of eastern Nepal *Q. mespilifolioides*
- (5) Cup enclosing less than half of acorn; leaves less than 15 cm long 6
- (6) Acorns almost spherical; margins of leaves toothed almost to base; veins 16–21 pairs *Q. oxyodon*
- (6) Acorns longer than wide; margins of leaves toothed in upper half only; veins 9–12 pairs *Q. glauca*
- (7) Cup covering base only of ripe acorn; acorn almost spherical; leaves of young trees and coppice shoots with spiny margins, of older trees entire, or mixed on same tree *Q. semecarpifolia*
- (7) Cup covering about half of acorn 8
- (8) Veins of leaves curved, forking before margin; leaves of two types, with either untoothed margins, or margins with weakly spiny teeth; leaves less than 8 cm long *Q. floribunda*
- (8) Veins of leaves straight, running into margin; all leaves with fine teeth on margin 9
- (9) Young shoots and under sides of leaves with dense white woolly hairs; upper side of leaves dull green *Q. leucotrichophora*
- (9) Young shoots and under sides of leaves with rust-coloured hairs; upper side of leaves dark, shiny green *Q. lanata*

Accounts of individual species

Lithocarpus elegans (Blume) Hatus ex Soepadmo

(Syn. *L. grandifolia* (D. Don) Biswas; *L. spicata* Rehder and Wilson;
Quercus spicata Sm., non Humb. and Bonpl.)
Nepali: arkaulo (arkaule, arkhola, adkaulo).

Leaves lanceolate to oblanceolate, 13–30 cm, glabrous, shining above. Fruit shining brown, depressed globose, about 1.5 cm in diameter; cup enclosing bottom third of acorn only, when fruits ripe. It is widely distributed between 600 and 2100 m. East of the Koshi River it is found in tropical and subtropical evergreen forest, from 600 m upwards, and in *Schima-Castanopsis tribuloides* forest usually above 1200 m. Near Pokhara it occurs in *Schima-Castanopsis indica* forest above about 1500 m. It is found in lower temperate mixed broadleaved forest between 1500 and 2100 m, right across Nepal, usually on moister sites. The seed in Jiri ripens about December; seed sown there at the end of March germinated from the end of May onwards, and the seedlings had reached 20 cm in height by October. In the IHDP area 50 seedlings were raised from 1 kg of seed (Neville, 1985d). According to Upton (1990) it is used for fodder on a small scale in Lalitpur District, between 1000 and 1700 m, and it is doubtless used in other places where it is plentiful. The wood weighs about 930 kg m⁻³; it does not warp and is durable. It makes good charcoal.

References: Gamble (1922); Troup (1921).

Lithocarpus fenestrata (Roxb.) Rehder

(Syn. *Quercus fenestrata* Roxb.)

According to the Enumeration (Hara *et al.*, 1982) this has not yet been recorded from Nepal, but as it occurs in Sikkim it may well occur in Nepal also, particularly in the east. It is mentioned by Panday (1982) under the Nepali name arkhaulo, but this may refer to *L. elegans* (see above). Arkhaulo seedlings seen in nurseries in the Charikot area were all *L. elegans*. It may be distinguished from *L. elegans* by the leaves being covered beneath by a dense felt of minute stellate hairs, and by the acorn being enclosed for three quarters or more of its length within the cup. The cups are often united in threes when young, but are not fused in large numbers, like the other species.

Lithocarpus grandifolia see *L. elegans*.

***Lithocarpus pachyphylla* (Kurz) Rehder**

(Syn. *Quercus pachyphylla* Kurz)

Leaves elliptic lanceolate, long-pointed, entire, 13–20 cm long, hairless or with a few minute stellate hairs on the midrib and veins beneath. Acorn depressed globular half to three quarters enclosed by the cup. This species is confined in Nepal to the area east of the Tamur River, between 2100 and 2800 m. The wood weighs about 800 kg m^{-3} and in the Darjeeling area is used for planking, palings and shingles. The bark and fruit are astringent and are used medicinally (Department of Medicinal Plants, 1970). The fruit ripens about November and there are about 350 seeds kg^{-1} . They are often damaged by insects, and hence the the number of plants per hundred seeds tends to be low (about six per cent; Suri and Seth, 1959). The tree takes about 20 years to reach a height of 12 m and a diameter of 15 cm, and the mean annual yield of fuelwood is estimated to be between 1.8 and 2.7 t ha^{-1} .

References: Gamble (1922); Suri and Seth (1959); Troup (1921).

Lithocarpus spicata see *L. elegans*.

Quercus dilatata see *Q. floribunda*.

Quercus fenestrata see *Lithocarpus fenestrata*.

***Quercus floribunda* Lindl. ex. A. Camus**

(Syn. *Q. dilatata* Lindl. ex A. DC.)

Nepali: belekharmendo; thinke (Jumla).

Leaves shining green, lanceolate to elliptic, up to about 8 cm long, with the veins branching short of the margin; margin spiny or smooth; leaves hairless beneath. Acorn about 2 cm long, ovoid, with a fine point, about twice as long as the cup.

Occurrence

Between 2100 and 2700 m, usually found on damp sites and north-facing slopes in *Q. leucotrichophora*-*Q. lanata* forest. Rare east of the Kali Gandaki River, and absent from eastern Nepal.

Silvicultural characteristics

A large tree 30 m or more. It tolerates side shade when young, but growth of older trees is better in the open. Best growth is on well-drained clay loam, and

on shallow gravelly soils growth becomes stunted. The tree is frost-hardy, but early frosts sometimes kill the seedlings. It does not tolerate drought. It coppices well, until the trees are about 10 cm in diameter; trees larger than this coppice poorly in many localities.

Regeneration

The seed ripens between August and October, and under natural conditions germinates soon after falling. In a good seed year abundant young natural seedlings will be found near to the seed-bearers, but many may die off during the next dry season, if exposed to the sun. In moist shady places dense thickets of seedlings may develop. There are 500–600 seeds kg^{-1} .

Rate of growth

In Jaunsar in India plantations (direct sown) averaged 4.3 m in height after 20 years, which is slow.

Uses

The wood weighs about 970 kg m^{-3} . In the Western Himalaya it is used for building and agricultural implements, and is one of the best oaks for timber. In India the leaves are much used as fodder; they contain 9.6 per cent crude protein, with a digestibility coefficient of 44 per cent. The total digestible nutrients are 43.2 per cent. It is a valued fodder in Jumla (B.D. Yadav, 1992).

References: Gamble (1922); R.V. Singh (1982); Suri and Seth (1959); Troup (1921).

Quercus glauca Thunb.

Nepali: phalant, sano phalant, sano pate phalant.

Leaves glabrous, shining above, paler beneath, with prominent parallel veins which run out in the margin to saw-like teeth in the upper half to two thirds of the leaf only; the apex of the leaf is a point, about 1 cm long, which is also without teeth. Cups have concentric bands of scales about half as long as the acorns.

Occurrence

From 450 to 3100 m. In eastern Nepal it grows occasionally in tropical ever-green forest, and it is common in *Schima-Castanopsis* forest and *Q. leucotrichophora-Q. lanata* forest, especially on moister sites. It is also a constituent of the lower temperate broadleaved forest. According to Dobremez (1976) it is a

secondary species in all oak forests up to about 2500 m but also forms some pure stands in moderately moist conditions. It is one of the species found in degraded *Schima-Castanopsis* forest after protection (Tamrakar, 1992).

Silvicultural characteristics

A large tree. The seedlings are tolerant to shade, but older trees benefit from full light; seedlings are sensitive to frost and must be protected during the winter, but older trees are more frost-resistant. The tree prefers moist situations, such as north aspects and the sides of the ravines, and grows well on deep clay loams. It should not be planted on dry sites. The seedlings are liable to be browsed. The tree coppices freely.

Regeneration

The seed ripens between October and December, according to the locality. The number of seeds per kilogram apparently varies a great deal; figures quoted range from 500 (M.W. Campbell, 1983a) to 840 (Panday, 1982) or to as high as 1900 (FAO, 1975). In most localities the seedlings will need about 15 months in the nursery to reach a height of 15 cm. Bare-root planting has given very poor results.

Performance in plantations and rate of growth

Survival in plantations between 1600 and 2100 m has usually been over 90 per cent, but early growth rates are slow, with a height of about 50 cm after two years.

Uses

The wood is hard and heavy, weighing about 930 kg m⁻³. It is used for house building, ploughs and other agricultural implements, as well as for fuelwood; it is slow-burning, but tends to produce rather a lot of bad-smelling smoke (Chaturvedi *et al.*, 1986). The fodder contains 9.6 per cent crude protein and the total digestive nutrients amount to 39.8 per cent (R.V. Singh, 1982). The new flush of leaves is in March, and fodder is lopped from April to July. Panday (1982) estimates a mean annual fodder yield of 80–100 kg per tree, fresh weight. Its use as fodder varies with the locality, as with most fodder species. It is the fodder most preferred in the upper elevation village in Myagdi District studied by Metz (1987), but elsewhere its use varies. It is used on a small scale in Lalitpur District at altitudes of between 1000 and 1750 m, especially in April, and no doubt it is used elsewhere. However in Dolakha District its popularity as a fodder was low; it was not found on farmers' land, and farmers were not interested in planting it (Robinson and Neupane, 1988). In Solok-

humbu, however, according to J. Stewart (1984) it was in high demand for planting by private farmers.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); R.V. Singh (1982); J. Stewart (1984); Troup (1921).

Quercus incana sec *Q. leucotrichophora*.

***Quercus lamellosa* J.E. Sm.**

Nepali: phalant, thulo phalant, bangset, bansi, bangsher, shalshi, pharat-singhali, bajrat, gogane, dabre.

Leaves oblong-elliptic, 15–30 cm long, dark green, with about 20 pairs of straight parallel veins, which in the upper three quarters of the leaf each end in a marginal tooth. Young leaves silvery or buff hairy beneath. Acorn globular 5–6.5 cm in diameter, covered for about three quarters of its length by a cup on which the scales are arranged in five or six horizontal bands.

Occurrence

It is found in east and central Nepal at altitudes of between 1600 and 2800 m; the westernmost occurrence is to the south of Dhaulagiri. In areas of high rainfall such as the ridges flanking the Arun valley, and south of the Himal Chuli and Annapurna Himal, it forms a more or less continuous belt between 1750 m and 2550 m. In drier places it is confined to north and west aspects. It is frequently associated with Lauraceae (*Litsea*, *Cinnamomum*, *Machilus*, *Lindera*, etc.) In wet areas it forms very dense forest with abundant epiphytes.

Silvicultural characteristics

A large tree over 30 m. Its natural occurrence indicates that it should only be planted in localities with a high annual rainfall; it grows well on deep, well-drained, moist soils, and on clay loams. Troup states that natural reproduction is particularly good where there are areas of nigalo bamboo (*Arundinaria* spp.), and this might serve as an indicator for suitable sites. The seedlings are moderately shade-tolerant, and are frost-resistant. The tree coppices well, but does not produce root suckers. Even old trees are sensitive to fire damage.

Nursery and plantation techniques

The seed ripens between October and December; about one year in three is a good seed year. There are from 25 to 30 seeds kg⁻¹, including the cups; 150–250 after removal of the cups. As with most oaks, if the seed is sown at the time of collection, in October or November, the seedlings will need at least 21 months

in the nursery, and in some places a year longer. Seed sown in March at Jiri (2000 m) produced seedlings averaging 34 cm in height by October in the following year, about 18 months later. If seedlings 20 cm tall are needed this indicates that March sowing, from stored seed, would be satisfactory in many places, but much depends on conditions in a particular nursery. *Quercus lamellosa* has a particularly vigorous taproot, and root pruning is extremely important. Troup (1921) records successful establishment by using four-year-old stumps 2.5 cm diameter at the root collar. In India this species is often sown directly in the forest.

Performance in plantations and rate of growth

There are only a few records of early growth in Nepal; the best height growth of 51 cm at the age of two years was recorded at Salle, Dhankuta District, altitude over 2000 m. At altitudes below 2200 m survival was on the whole good, over 80 per cent, except and at Murtidungha (1500 m) with 55 per cent survival at two years old. This appears to be a generally poor site. At Simkhara (2400 m) both survival (45 per cent) and height growth (19 cm), at the age of two and a half years were low; in Solokhumbu at 2500 m only two per cent of the trees planted in 1983–1984 survived. As far as can be judged from two records plantations at these high altitudes are unlikely to succeed, although it is within the natural altitude range of the species. According to Troup in plantations in the Darjeeling Hills the following figures for height growth were obtained: two years, 61 cm; five years, 122 cm; ten years, 244 cm; 20 years, 671 cm. In this area heights in natural forest, after the age of four years, averaged nearly double these figures; at 20 years old in natural forest the trees averaged 12.2 m in height by 14.6 cm in diameter. This lower growth of planted compared with natural seedlings is unusual, and suggests that the data refer to different soil types.

Uses

The wood weighs about 940 kg m⁻³, and is hard and durable. In the Darjeeling area of India it is used for posts, beams, rafters, doorposts and window frames. It is a good fuelwood. The leaves are used as fodder and contain (dry) ten per cent crude protein (Panday, 1982). According to Wood *et al.* (1992) the tannin content was moderately high, but did not vary a great deal between November and March. In the village in Myagdi District, at about 1800 m, studied by Metz (1987) it was the third preference as a fodder tree (after *Q. glauca* and *Q. semecarpifolia*) but elsewhere its use is rather sporadic. In the parts of Dolakha District between 1500 and 1800 m studied by Robinson and Neupane (1988) it was low in the order of preferred species; it was absent from farmers' land and

none were interested in planting it. It is not included in the fodder trees used in Lalitpur District recorded by Upton (1990).

References: M.W. Campbell (1983a); Gamble (1922); Kessler (1981); Lamichhancy and Joshi (1980); Panday (1982); Suri and Seth (1959); Troup (1921).

***Quercus lanata* Sm.**

(Syn. *Q. lanuginosa* D. Don.; *Q. pubescens* Willd. of some Nepal publications)

Nepali: banjh, thulo banjh, banga, sano phalant.

Leaves saw-toothed but not spiny, dark shiny green above, with rust-coloured woolly hair beneath. Acorn oblong, about 1.5 cm long, a third to a half enclosed in the cup.

Occurrence

It occurs mainly in a belt at 1750–2400 m, in the west commonly associated with *Q. leucotrichophora*. In gullies it may descend to 1200 m. It is widespread in western Nepal, but in central Nepal it tends to be confined to dry south-facing slopes where the trees are usually rather small, less than 15 m, and open, and are associated with *Rhododendron arboreum* and *Lyonia ovalifolia*. In wetter areas the trees are taller, to 24 m, and often have abundant epiphytes; they are associated with a number of other species including *Carpinus*, *Ilex diphyrena* and Lauraceae. In places *Q. lanata* is also associated with *Pinus wallichiana*. It is almost completely absent from very high rainfall areas, such as the southern flanks of Annapurna Himal and Himal Chuli, and the wetter parts of the Arun and Tamur valleys.

Silvicultural characteristics

The seedlings will tolerate some shade. The tree occurs in regions where the minimum temperature is from -4°C to -7°C, so it must be frost-tolerant. It grows on a variety of soils, including those derived from limestone. It coppices well.

Nursery and plantation techniques

The seed ripens between November and February. There are about 1800 seeds kg⁻¹, including cups. Germination of fresh seed is good, about 80 per cent. The seed is very liable to insect attack.

Performance in plantations and rate of growth

No records from trial plots are available; survival in community forestry plantations has tended to be low. In India Troup (1921) records a height growth of 50 cm in four years from seed. Older trees may grow faster and Troup records a mean annual diameter increment of nearly 1 cm from trees in a thinned plot having a mean diameter of 12 to 20 cm.

Uses

The wood weighs 880 kg m⁻³, and is used mainly for fuelwood. The leaves are used for fodder, but no analyses are available. The new flush of leaves occurs in May and June, and the tree is lopped between November and April; one tree is estimated to produce 50–80 kg of fodder (fresh weight) per annum (Panday, 1982). Its use as fodder is rather local; it is recorded from Lalitpur District, on a small scale. In the village in Myagdi District studied by Metz (1987) it is cut and fed to animals when they are on arable fields. In other cases it is difficult to separate records from those of *Q. leucotrichophora*, also called banjh in Nepali.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Panday (1982); Troup (1921).

Quercus lanuginosa see *Q. lanata*.

***Quercus leucotrichophora* A. Camus**

(Syn. *Q. incana* Roxb.)

Nepali: banjh, sano banjh.

Similar to *Q. lanata*, but the leaves have dense, white, woolly hairs beneath, not rust-coloured.

Occurrence

In a belt between 1650 and 2400 m, associated with *Q. lanata*. West of the Karnali River it is more abundant than *Q. lanata*, which there tends to be confined to south-facing slopes. Further east it becomes scarce and east of the Kali Gandaki is rare or absent.

Silvicultural characteristics

A medium-sized tree, usually attaining about 15 m in height, occasionally 24 m. Young seedlings up to two years old are very shade-tolerant, thereafter the tree needs moderate to full light. It needs moderately fertile soils, growing well on clays derived from shales and clay loams, but does not do well on dry sites.

It is sensitive to fires and browsing. Up to a diameter of 25–30 cm the tree coppices well, but larger trees coppice badly if at all. It is one of the species found in regrowth of degraded *Schima-Castanopsis* woodland.

Nursery and plantation techniques

The seed ripens between November and March, according to the locality, but ripe seed may remain on the trees for several months. About one year in two is a good seed year. In nurseries in the IHDP area an average of 700 plants were raised per kilogram of seeds.

Rate of growth

Few records of trial plots are available. What there are indicate a height of about 40 cm at 1.5 years and 70 cm at 2.5 years, with a survival rate of 90 per cent or more, with the exception of Simkhara (2400 m) where at 2.4 years survival was 70 per cent and mean height 16 cm, indicating stagnation. According to Troup (1921) in a plantation 32 years old the trees averaged 17 m in height by 17 cm in diameter, with a mean annual increment of about $9 \text{ m}^3 \text{ ha}^{-1}$; but this was considered to be considerably above the average.

Uses

The wood is very heavy, weighing about 1020 kg m^{-3} . The calorific value of the heartwood is 19,100 and of the sapwood $19,400 \text{ kJ kg}^{-1}$ (Hawkins, 1982); hence it is a good fuelwood. It is not a good timber as it warps and splits badly, but is used occasionally for low-grade construction and agricultural implements (Gamble, 1922). Because of its abundance it is a very important fodder tree in some localities. In Dehimando Panchayat of Mahakali Forest Division 78 per cent of all privately owned fodder trees were of this species (Hawkins and Malla, 1983). Together with *Q. lanata*, which has the same Nepali name, it is also used on a small scale in Dhading District. In Dolakha District it was of relatively low popularity, but a few farmers would be prepared to plant it. The leaves contain 8.2 per cent crude protein according to Panday (1982), 8.7 per cent (D. Bajracharya *et al.*, 1985), but R.V. Singh (1982) gives rather higher figures, ranging up to 12.6 per cent, and averaging about 10.6 per cent. The trees are lopped for fodder from December to June. An infusion of the gum from old trees is used to treat colds, and as an analgesic. The air-dry bark contains about 22 per cent tannin (Gamble, 1922).

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); Mader and Stewart (1983); R.V. Singh (1982); Streets (1962); Suri and Seth (1959); Troup (1921).

Quercus mespilifolia see *Q. mespilifolioides*.

***Quercus mespilifolioides* A. Camus**

(Syn. *Q. mespilifolia* Wall. ex A. DC., non Wallr.)

Leaves elongate-elliptic, 10–20 cm long, saw-toothed to near the base, velvety below when young but becoming hairless except on midrib. Acorns about 2.5 cm in diameter. A rare oak from eastern Nepal, between 2300 and 2500 m. No further information available.

***Quercus oxyodon* Miq.**

(Syn. *Q. lineata* B1. var. *oxyodon* Hook. f.; *Q. lobbii* var. *oxyodon* (Miq.) Wenzig.)

Nepali: phalant.

The tree referred to as *Q. lineata* probably belongs here (see Stainton, 1972). Leaves lanceolate, green above, glaucous beneath, with prominent straight parallel secondary nerves ending, in the upper three quarters of the leaf, in marginal teeth. Acorns hemispherical about 2 cm in diameter, half enclosed by the cup. Very close to *Q. glauca*, of which it may be a variety. Found in east and central Nepal between 1700 and 2800 m; its western limit is the Buri Gandaki-Marsyandi rivers. Often associated with *Q. lamellosa* and *Q. glauca*. Wood weighs about 1030 kg m⁻³ (Gamble, 1922).

Quercus pachyphylla see *Lithocarpus pachyphylla*.

Quercus pubescens see *Q. lanata*.

***Quercus semecarpifolia* Sm.**

Nepali: khasru (kharsu, kharshu, karsu), ghesi.

Note: The specific name is often wrongly spelt *semicarpifolia*. It is derived from *Semecarpus anacardium*, the marking nut tree, from a supposed similarity (admittedly not very obvious) of the leaves of the two species.

Leaves dark glossy green above, generally with rust-coloured hairs beneath, but old leaves almost hairless. The leaves of young trees and coppice shoots have sharp spines on the margins, but in older trees the margins are smooth. The ripe acorns are dark brown, almost black, globular in shape, 4–5 times as long as the greyish cup.

Occurrence

It grows between 1700 and 3800 m, but is commonest between 2400 and 3000 m, and is the highest-altitude oak in Nepal. In western Nepal it is dominant in forests between 2400 and 3000 m, except on very moist north-facing slopes, but in central and eastern Nepal it tends to be confined to warmer, drier south-facing slopes. It is absent from the very high rainfall areas north of Pokhara, and in the upper Arun and Tamar valleys. In the Humla-Jumla area it is dominant, with *Abies spectabilis* and *Betula utilis*, especially on south-facing slopes, at above 3000 m.

Silvicultural characteristics

The tree grows to about 25 m, sometimes 30 m high. It is a strong light-demander from the seedling stage onwards. The seedlings, which are leafless during the cold weather, are resistant to frost. It needs moderately fertile soils; it will survive on poor rocky ridges, but there its growth is poor. It occurs naturally on limestone as well as many other types of soil, and tolerates a wide range of pH. It coppices and pollards fairly well.

Nursery and plantation techniques

The seed ripens between June and August, and germinates as soon as it falls; sometimes it even begins to germinate while still on the tree (Troup, 1921). About one year in three is a good seed year. There are 150–200 seeds kg⁻¹. If the seed is sown immediately after it has been collected 95 per cent or more germination can be expected. The development of the seedling has some peculiar features. After emergence of the radicle, the petioles of the cotyledons unite into a tube with the young taproot at the base; this fairly rapidly reaches a length of 10 cm or more. Often during the first season the stem only reaches a length of 5 to 8 cm, and remains without normal leaves, which are replaced by scales with buds in their axils; normal leaves only develop in the second year. However under favourable conditions normal leaves may develop in the first year. While the stem continues to grow slowly a long taproot is being developed; often the stem will die back at the end of the first season, and for some successive seasons, until continued upward growth finally begins (Troup, 1921). The seedlings will need two years in the nursery. The slow rate of stem growth, and rapid taproot development, suggests that the use of extra large containers would be desirable. Really satisfactory nursery techniques have still to be developed. Direct sowing has been used in India, and would merit further trials. Naturally grown seedlings, dug up and planted bare-root in plantations, gave poor results on a ridge top in Doti District at 1800 m (J. Stewart, 1983a).

Performance in plantations and rate of growth

It has not been planted to any great extent, even in trial plots. At Simkhara (2400 m) at the age of 2.4 years survival was 70 per cent, and the mean height 16 cm, which means that the seedlings can have grown very little since they were planted. In Solokhumbu District in 1983 survival in one plantation of a thousand trees was less than four per cent (J. Stewart, 1984). It is clear that there are unsolved problems in nursery and plantation techniques. Information from outside Nepal indicates that growth is very slow. In Jaunsar, India, in a plantation 20 years old, the trees averaged 2.2 m in height by 4.5 cm in diameter.

Uses

The timber is hard and heavy, 860 kg m⁻³; it is a good construction timber, and an excellent source of fuelwood and charcoal. It is a very important source of dry season fodder, especially at altitudes of over 2000 m, where it is the most abundant fodder species. In the upper elevation village in Myagdi District studied by Metz (1987) it was the second preferred fodder species, after *Q. glauca*. According to Panday (1982), the leaves contain 7.3 per cent crude protein. R.V. Singh (1982) quotes a nitrogen content of 4.4 per cent, equivalent to 8.2 per cent crude protein. The leaves are lopped between November and April. At high altitudes one tree will produce 30–40 kg yr⁻¹ dry weight; at rather lower altitudes one tree will produce 120–200 kg yr⁻¹ fresh weight (Panday, 1982). In government oak forests lopping is 'indiscriminate, heavy, and continual' (Mathema, 1991b), resulting in trees which are reduced to poles clothed in very short leafy branches. Privately owned trees are treated with much more respect. Only two-year-old foliage is taken, and only the tips of the branches are cut. This produces trees with rounded crowns, capable of sustained production of fodder, and also producing acorns for regeneration of the forest.

Importance in Nepal

Maintenance of this very valuable fodder resource is important, but creation of plantations, apart from dibbling in seed in blanks, is much less important than management of the natural forest, especially by encouraging conservative and sustainable methods of lopping the trees for fodder.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); Panday (1982); R.V. Singh (1982); Suri and Seth (1959); Troup (1921).

Rhododendron L.

Ericaceae

Rhododendron arboreum Sm.

Nepali: lali gurans (red-flowered form), guruns, bhorens, ghorans, dotyal, taggu.

Tree up to 15 m tall. Leaves 10–20 cm long, glossy green, with white or brown hairs on underside. Flowers 10–13 cm across, blood red at lower altitudes, pink or white at higher elevations. This tree, which is the national flower of Nepal, occurs between 1500 and 3300 m but is commonest above 2300 m, where its deep red flowers make it a conspicuous feature of the landscape in spring. It is found in a great variety of vegetation types, and sometimes forms almost pure forest in limited areas. Unlike many species of *Rhododendron*, *R. arboreum* grows on a wide range of soils, and is not confined to acid soils. The leaves are unpalatable to browsing animals, and overgrazing favours the spread of the species.

The seed ripens between August and March, according to the altitude. The seeds are minute, about $12 \text{ million kg}^{-1}$. They are extracted by drying the capsules on a piece of paper in the sun. The seed should be sown in beds or boxes, the surface soil of which is well levelled, in a similar technique to that used for *Alnus nepalensis*. They are pricked out into polypots when two leaves have appeared. Growth of the seedlings is slow; during the first season they reach only a few millimetres in height, with two or three true leaves. The young seedlings are very sensitive to drought, and should be kept under shade. Rather than raising the plants from seed, Troup (1921) recommends transplanting small natural seedlings to the nursery, and keeping them there until they are large enough to plant out.

The wood weighs about 640 kg m^{-3} , and is widely used for fuelwood. It is also used for making small wooden vessels and utensils and for *khukuri* (knife) handles, but it warps badly and shrinks during seasoning (Gamble, 1922; T.B. Shrestha, 1984b). The flowers are eaten as *achar* (pickles), and fresh flowers are believed to be able to dissolve fish-bones stuck in the throat; the young leaves are applied to the forehead to cure headaches. The red sticky shoots if eaten by cattle cause vomiting, flatulence and dyspepsia, and older leaves are unpalatable (Bhandary and Shrestha, 1984).

It is not planted very much, and a more urgent task than establishing plantations is the protection and, where appropriate, the rational management of natural stands. Altogether about 30 species of *Rhododendron* are found in

Nepal. In some localities, over 2500 m, species of *Rhododendron* form almost pure forests. Some species reach an altitude of over 5000 m. Many are planted in temperate countries as ornamental trees.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); T.B. Shrestha (1984b); Troup (1921).

Robinia L.

Papilionaceae

Robinia pseudoacacia L.

False acacia, black locust, robinia.

Tree up to about 25 m tall. Branchlets with paired thorns. Leaves pinnate with an odd terminal leaflet; leaflets ovate, rounded at apex, 2.5–5 cm long. Flowers white, in pendulous racemes. A native of the United States, from Pennsylvania to Georgia and as far west as Iowa and Oklahoma. It appears to be a species which needs an appreciable amount of winter rainfall or snowfall to grow well; it has been successfully planted in Kashmir and Himachal Pradesh in the northwest Himalaya, but further east results are much poorer. There are from 35,000 to 80,000 seeds kg⁻¹. The seed can be stored for ten years or more; it should be treated with hot water before it is sown. It can be sown directly into polybags, and will need 4–9 months in the nursery before it is planted out. In Nepal it was fairly widely planted about 1983, but with poor results; survival in Community Forestry Project plantations in 1983 was less than ten per cent (Community Forestry Development Project, 1984). It failed in trial plots at Syangja, Tistung and Kharidhunga. Any future plantings of this species should be restricted to small-scale trial plots, to be observed for three or four years, before any more large-scale plantations are attempted.

References: M.W. Campbell (1983a); Ghosh (1977); R.V. Singh (1982); Streets (1962); Troup (1921); Webb *et al.* (1984).

Salix L.

Salicaceae

Willow

Nepali: bainsh, tissi.

Trees and shrubs. Leaves alternate, elliptic, or lanceolate, usually long and narrow. Flowers small, in catkins, the male and female on different trees; sepals and petals absent. There are about 30 species of *Salix* in Nepal, ranging in size from moderately large trees to prostrate alpine shrubs. As field identification of *Salix* species is rather difficult, little accurate information is available on the distribution of the various species. The most important in Nepal are *S. tetrasperma* Roxb., *S. disperma* Roxb. ex D. Don and the introduced *S. babylonica* L. *Salix* species, with *Populus* species, are particularly important in the dry Mustang region where they are often the only trees available. All the tree *Salix* grow best in moist soils, such as near streams and irrigation channels; they will withstand a considerable degree of waterlogging and thus are suitable for planting on swampy areas, provided the soil has not too high a clay content. They are very subject to browsing damage. They are propagated by cuttings similar to those used for *Populus* species, and can be raised from large cuttings 2–2.5 m long by 5–7 cm in diameter. Most species coppice and pollard well. Many of the *Salix* species seen in Nepal are of very poor form. In taking cuttings for plantations care should be taken to select them from as straight growing trees as possible. *Salix* of unspecified species have been included in some trials, but results in general have been only mediocre, perhaps as a result of the trees being planted on dry sites. Healthy plantations have been established in some areas, for instance near Surkhet. The wood is soft, light, porous and even-grained. In many places the twigs are woven into baskets, and wattles for house-building.

General references: M.W. Campbell (1983a); FAO (1979); Ghosh (1977).

Salix babylonica L.

Tree up to 20 m high; branches somewhat pendulous. Leaves 4.5–9 cm by 0.7–1.5 cm, margins regularly toothed, glabrous. Catkins appearing before the leaves, their stalks with a few small leaves 1–2 cm long. *Salix babylonica*, a native of China, was introduced into other parts of the world, including Nepal, very many years ago. Presumably it has been largely propagated by cuttings, as only the male tree is common. In Nepal it has been recorded from 1400 to 3650

m; it has been widely planted in the Kathmandu Valley. Growth is fairly fast, the mean annual diameter increment being 1.0–1.3 cm. The tree, however, tends to be rather short-lived. The wood is white. The twigs are used for basket-making, and the leaves (March to November) for fodder; leaves with 68 per cent moisture content contain 7.5 per cent crude protein (R.V. Singh, 1982). The leaves and bark are tonic and astringent, and used for treating fevers; the bark is anthelmintic (Department of Medicinal Plants, 1970). (Aspirin, acetylsalicylic acid, was originally derived from salicylic acid obtained from willow bark.)

References: Gamble (1922); Lamichhaney and Joshi (1980); Streets (1962); Troup (1921).

***Salix disperma* Roxb. ex. D. Don**

(Syn. *S. wallichiana* Anderss.)

Shrub or tree to 10 m tall. Leaves 5.5–14 cm by 2–5 cm, margins toothed, lower surface with grey hairs. Catkins appearing before leaves, sessile or on stalks up to 1 cm long. Recorded from Nepal between 1500 and 3500 m. It is usually a large shrub, but sometimes becomes a small tree. The wood is light pinkish-brown, and weighs about 510 kg m⁻³. The leaves are used for fodder.

References: R.V. Singh (1982); Troup (1921).

***Salix tetrasperma* Roxb.**

Tree up to 15 m tall. Leaves 6–10 by 2–4 cm, with glandular teeth on margin, dark green above, greyish below. Catkins appearing with young leaves, their stalks with small leaves similar to foliage leaves. Found along streams in Nepal from the Terai to 2700 m. It is usually a moderate-sized tree but occasionally reaches large dimensions. It is a light-demander and frost-hardy. It will withstand flooding; when subject to inundation it often sends out small rootlets near the base of the stem. Growth is fast. Natural trees have a mean annual diameter increment of 0.7–2.5 cm, and in a plantation at Delhi Bela, India, the mean annual diameter increment ranged from 2 to 2.5 cm (Troup, 1921). The wood is red and weighs about 500 kg m⁻³. In India it is used for posts and planks, and has been used for charcoal for gunpowder. The twigs are used to make baskets. The leaves are lopped for fodder particularly for sheep and goats; the leaves contain about two per cent nitrogen, equivalent to about 12 per cent crude protein (R.V. Singh, 1982). The tree is deciduous between about November and March, and hence produces no fodder during this period.

References: Gamble (1922); R.V. Singh (1982); Troup (1921).

Salix exigua Nuttall, from North America, was tried in Nisikot, Dhading District (1400 m) but had poor survival and height growth (S. Rimal, 1992).

Santalum L.

Santalaceae

Santalum album L.

Nepali: shri khand, chandal.
Sandalwood.

Small evergreen glabrous tree. Leaves opposite, 3.5–6.5 cm long, entire. Flowers brownish-purple, in branched inflorescences. Fruit a black drupe about 1.2 cm in diameter. This tree, greatly prized for its fragrant timber, is said to grow in Gorkha District (Majupuria and Joshi, 1988), but details are scarce. Seed was also introduced to Nepal in 1983 (P.M. Amatya, 1987), and since then a few trees have been established in the Terai, and trials have been made in the Koshi Hills Development area in eastern Nepal. The tree is a root-parasite of other species of trees, and must be grown in contact with a suitable host, for instance by raising seedlings of *S. album* and the host plant in the same polythene pot. Often a relatively short-lived primary host is used in the nursery, followed by a more permanent secondary host which is planted near to the *S. album* tree a few months after the latter has been planted. Suitable primary hosts for Nepal include *Sesbania* species and other small legumes, *Amaranthus* species, *Capsicum*, tomatoes and *Calotropis* species. Among secondary hosts are *Acacia catechu*, *A. nilotica*, *Albizia* species, *Cassia siamea*, *Dalbergia sissoo* and *Terminalia arjun*. There are about 4000 fruit stones kg⁻¹. Germination is slow and irregular, and to obtain 80 per cent germination up to seven months may be needed. Thus the seed should be scarified and soaked in water before it is sown in trays containing a mixture of one part of sand to three parts of soil, treated with fungicide and nematicide. The seedlings should be pricked out at the four-leaf stage into large plastic pots (13 cm x 30 cm) in which the host plant is also planted. Fifty per cent shade is needed in the nursery. Suitable areas for planting would have temperatures ranging from 10–35°C, with no frosts, and fairly moist deep soils. Saline and calcareous soils should be avoided. Host trees should be planted not more than 2 m from the *S. album*. Dibbling in scarified seed near to suitable host species could also be tried. For

more details of the silviculture of *S. album* see Neil (1990c). See also Troup (1921).

***Sapindus* L.**

Sapindaceae

***Sapindus mukorossi* Gaertn.**

(Syn. *S. detergens* Roxb.)

Nepali: ritha.

Tree up to 18 m tall. Leaves equal pinnate, with several pairs of lanceolate leaflets. Flowers small, purple, in a much-branched terminal inflorescence. Fruit fleshy, with a single stone, about 2 cm long.

Occurrence

Probably indigenous in Nepal between 1000 and 1200 m, but it has been widely planted, both in Nepal and many other countries of tropical Asia.

Silvicultural characteristics

The seedlings are said to stand frost moderately well. The tree is fairly tolerant to low soil fertility, but will not grow on very poor, rocky sites.

Artificial regeneration

The seed ripens between September and February. It can often be obtained from places where people wash clothes, as it is discarded after the pulp has been removed as a soap substitute. There are 600–900 seeds kg⁻¹. It can be stored for a year. Before the seed is sown it should be put in hot water, and left in it for seven days; if this is not done, germination may be greatly delayed. Also seed sown in autumn will usually not germinate until the following spring. Treated seed sown in February–March will usually germinate within 4–6 weeks. Untreated seed takes 2–4 months to germinate, and germination is very irregular. Germination percentage is usually good; the average number of plants produced from eight nurseries in 1982 was 360 from one kilogram of seed, with some nurseries producing 600. The seed should be sown directly into polypots, with one or two seeds per container. Seed sown in February–March will provide plantable stock by the rains. Very frequent root pruning is essential; once a strong taproot has been allowed to develop outside the plastic pot, pruning the root is likely to kill the plant. It was reported by Thunberg and

Werner (1981) that bare-root plants had been used successfully in Ilam District. However a later report from Ilam (Olsson, 1983) does not confirm this; only 29 per cent of the trees planted 1981–1982 survived, though it is not stated how many of these, if any, were from bare-root stock. In Darchula District, in the far west, Wilson (1988) reports that bare-root plants could be used if planted in winter when they were dormant, but in general survival of bare-root plants was only 30 to 50 per cent. She also says that stumps could be used. Troup (1921) states that stumps from two-year-old seedlings can be used for planting, though a certain amount of mortality may be expected. He also reports that propagation by cuttings is possible. Growth in plantations is reported to be slow, and survival has often been poor. For the planting years 1981 and 1982 the Community Forestry Development Project reported a survival rate in plantations of only 27 per cent, and in farmers' private plantings of 43 per cent (J.G. Campbell and Bhattarai, 1983b). This suggests that it has often been planted on unsuitable sites. For fruit production wide spacing should be used.

Uses

Its main use is for its fruits, the pulp of which is used in place of soap for washing clothing. It is also used medicinally as an expectorant and in the treatment of epilepsy, and as a fish poison. According to the Department of Medicinal Plants (1970) about 4000 *maund* of the fruit (approximately 150 t) are exported annually from Nepal. The wood weighs about 700 kg m⁻³ but is little used, presumably because of the value of the tree for its fruits. The leaves are occasionally used for fodder, but according to R.V. Singh (1982) this is of poor quality. It is not included in Panday's (1982) list of fodder trees.

Importance in Nepal

Because of the value of the fruits as a soap substitute some people are prepared to plant the tree. However the ease of obtaining the seeds, and of growing plants in the nursery, have resulted in *Sapindus* having been raised on a larger scale than is probably justified, especially in view of its relatively poor performance in plantations. It is more suitable for individual farmers to plant near their houses, than as a plantation tree.

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Lamichhane and Joshi (1980); Mader and Stewart (1983); J. Stewart (1983b); Troup (1921).

***Saurauia* Willd.**

Sauraiaceae

***Saurauia napaulensis* DC**

Nepali: gogan, tingir.

Small to medium tree. Leaves 20–35 cm by 6.5–12 cm, apex acuminate, base rounded, margins with fine teeth; 30–35 pairs of straight prominent veins. Flowers about 1.5 cm in diameter, pink, in branched axillary inflorescences. Fruit a globose berry, about 8 mm in diameter.

Natural occurrence

It is found in most parts of Nepal between 750 and 2100 m, often in farmland. Outside Nepal it extends from Garwhal to Arunachal Pradesh in the Himalaya, and as far as Indochina and west China.

Silvicultural characteristics

It is fairly tolerant to shade, and moderately tolerant to soil of low fertility. The seedlings show some susceptibility to frost, and some were killed in Ilam District, at 2000 m (Olsson, 1983).

Artificial regeneration

In eastern Nepal the main season for the fruit to ripen is in March and April, though a few trees fruit in May and also from September to November (Kessler, 1981). The ripe fruit is reddish in colour and contains brown seeds immersed in a jelly-like substance. If there is no jelly or the seeds are white, they are unripe. If the seed is to be stored it is necessary to extract it from the jelly. This may be done by squeezing the jelly and seed into a bucket half full of water, and then stirring the mixture. After a few hours the jelly will have partly dissolved in the water, while the seed has sunk to the bottom, though some jelly will remain with it. The water is carefully decanted and the process repeated until the seed is quite clean; this will take about two days. Another method is to put seed and jelly into a muslin bag, and squeeze this in water, changing the water several times; when all the jelly has been removed the bag containing the seed is dried. If the seed is to be sown at once the jelly containing the seed can be squeezed directly on to the soil surface.

There are 4–8 million seeds kg^{-1} . Seed separated from the jelly, and carefully dried, can be stored for a year in sealed polythene bags. In the laboratory 80 per cent germination has been recorded, and at Chalnakhel nursery up to 78 per

cent in experiments; however there is often considerable mortality among young seedlings, so that the eventual plant percentage tends to be low. Best results recorded from community nurseries were equivalent to about 350,000 seedlings kg^{-1} of seed, but it should be possible to improve a great deal on this. Germination in warmer localities takes 2–6 weeks, but in colder areas may take more than 20 weeks if the seed is sown in autumn.

As the seed is very small special care is needed in germinating it. It should be sown in trays filled with a mixture of one part sand to one part sieved soil at the rate of 2 g m^{-2} , and covered with a layer of sand just deep enough to cover the seed. Burslem (1989a) studied the effects of different methods of watering on germination, and found that best results (78.5 per cent germination) were obtained by watering from below with the seed tray standing in a larger tray filled with sand. In this experiment good germination (70 per cent) was also obtained by covering the seed tray with 1 cm of rice husks, as a mulch, and watering using a coarse rose. Mulches of straw or newspaper gave poorer results. Watering using a coarse rose, without mulch, gave the lowest germination percentage, 19.6.

The newly germinated seedlings should be protected against rain by waterproof shade, or by being kept in a shed. They should be pricked out when the rosette of leaves is about 2 cm in diameter, usually 6–8 weeks after sowing. Large polypots (10 cm x 18 cm) should be used, filled with a good potting mixture containing 20–25 per cent of well-rotted compost. In pricking out young seedlings, which have a rosette-like habit, care should be taken that the leaves are not in contact with the soil, as if this happens they are liable to rot. On the other hand if the seedlings are not pricked out deeply enough the roots may be exposed. Thus they should be planted at exactly the depth they were in the seed bed. The seedlings will need shade and protection from heavy rain after pricking out, until they are well established (2–4 weeks). Early growth is slow, so the seed should be sown in the March or April, before the monsoon. The seedlings will then be big enough to withstand the winter, during which they will need to be protected against night frosts by shading. At the end of the cold weather root pruning and spacing will be needed. They will thus need 14–15 months in the nursery, after which they should be 20–30 cm tall.

Saurauia napaulensis has also been raised by sowing directly into polythene pots. The seed plus jelly is squeezed out from the fruit, and one fruit is sufficient for about five pots. This method can only be used with freshly collected fruits. It can also be propagated by cuttings. Napier (1988) obtained 62 per cent rooting from cuttings taken from two-year-old hardwood, and set in March into 10 cm x 18 cm polypots containing a 3:1 soil:sand mixture. Of cuttings taken from one-year-old hardwood only eight per cent rooted.

In Pakhribas nursery successful rooting was obtained from stem cuttings 20–30 cm long and 2–3 cm diameter which were split into two and laid horizontally, with the split face downwards, in nursery beds. Farmers propagate *S. napaulensis* by using large cuttings set directly into the ground at the planting site. In view of the somewhat complicated techniques needed to raise *S. napaulensis* in the nursery the use of cuttings could well be the most practical way of propagating the species.

Plantations

A trial of different planting dates, at Pakhribas (1700 m), gave, after one year, 100 per cent survival for seedlings planted in May, June and August, 42 per cent in September, 33 per cent in October, eight per cent in April and nil in November. Thus *S. napaulensis* does not tolerate out of monsoon planting in this area (L. Joshi and Sherpa, 1992). In the same locality adding six *mana* (3.4 l) of compost per pit, and mulching with ban mara, both increased mean height after two years to 59 cm, as compared with 47 cm for the control. Mulching with black polythene sheet had negligible effects. Even with the extra treatments height growth in this trial is not very good. Addition of compost also increased height and survival of *S. napaulensis* planted in the open at Tistung (1900 m). Here planting in the shade of *Pinus greggii* increased survival from 50 to 100 per cent.

Performance in plantations and rate of growth

In general survival in trial plots has been good at middle altitudes (1300 to 2000 m). No data are available from outside these limits. At Chalnakhel (1370 m) the mean height at 18 months was 1.9 m. This was on an area which had been weeded, thoroughly cultivated and fertilized, and so can be regarded as optimum for the particular site. It ranked third on this site, after *Ficus semicordata* (rai khanyu) and *Litsea cubeba* (Napier and Parajuli, 1987). At other sites growth has been poorer.

Y.B. Malla (1988) measured 32 trees of known age on farmers' lands in the Pakhribas area. The results may be slightly selective, as farmers may not have kept badly growing trees. The following table (Table 59, page 704) summarizes the results, derived from Malla's figures after smoothing out by the use of regression equations. Early growth was rather slow, compared with *Ficus auriculata* and *F. semicordata* (rai khanyu) but after the age of five growth speeded up, and by eight years old *S. napaulensis* was the biggest tree of those measured. These figures are from a relatively small sample in a single locality but may give some idea of the growth that can be obtained from trees looked after by farmers.

Natural regeneration

The capsules split open on the trees to release the winged seed which is dispersed by the wind. Good seed years are frequent and natural seedlings are found wherever there is light enough. This includes in plantations of *Pinus* species: at Tistung it was the second most abundant natural broadleaved seedling colonizing a five-year-old plantation (Thompson, 1988b).

Artificial regeneration

The seed ripens between January and April. The ripe fruits remain on the trees for some time, so the collecting period can be extended. Abundant supplies of seed are available annually. There are between 160,000 and 350,000 seeds kg⁻¹. The seed is extracted by placing the fruits in the sun for a few days, until they open, when the seed can be shaken out, or extracted by gentle threshing. According to much of the literature, viability of the seed is short, and it should be sown immediately after collection; however Kessler (1981) states that there is no difficulty in storing the seed. The seed should be sown in beds or trays. Germination usually takes between ten days and three weeks. The seedlings should be pricked out into polythene pots when the first true leaves appear, after about ten weeks. Germination rates are usually rather low. The best result from nurseries in Nepal has been about 85,000 seedlings from 1 kg of seed, about 40 per cent germination, but the median figure is only about 5000 seedlings. Growth in the nursery is slow, and in most places, seed sown in March or April will only produce plantable stock by the monsoon a year later, i.e. the plants will need about 15 months in the nursery. Trials at Pakhribas (1700 m) gave 92 per cent survival for trees planted in August, 50 per cent for May and September, 33 per cent for April and October, 25 per cent for June, and eight per cent for April (L. Joshi and Sherpa, 1992). The June figures are anomalous; otherwise monsoon planting is clearly indicated. Compared with other species in this trial survival of *Schima* was generally poor. Trials of bare-root plants have failed.

Performance in plantations and rate of growth

Survival in trial plots has been very variable. In most trials in Tistung (1900 m) it failed, although healthy natural regeneration was found under *Pinus* trees in plantation. Elsewhere survival has ranged from 35 to 100 per cent. In farmers' plantings also survival has varied considerably; in south Lalitpur District it ranged from four per cent to 80 per cent (Hausler, 1990). In trial plots in Nepal early growth has been roughly similar to that of many species in the Middle Hills, averaging about 80 cm in height at 2.5 years. One natural seedling found in a neglected trial plot at Pipal Chaur in the Kathmandu Valley (1350 m) had

reached a height of 4.3 m by 6.0 cm dbh, eight years after the trial had been established; hence its age is presumably less than that (H.B. Thapa and Budathoki, 1987). In Assam in India, in a mixed *Shorea robusta*-*Schima* plantation 22 years old, the *Schima* averaged 17 m high by 22 cm in diameter; the *Schima* grew slightly faster than the *Shorea robusta* (Forestry Research Institute, 1975). At Kalimpong in a six-year-old plantation the mean diameter was about 11.5 cm (Ghosh, 1977).

Uses

The wood is light reddish-brown, moderately hard, and weighs about 690 kg m⁻³. The calorific value is about 20,500 kJ kg⁻¹, and it is a valued fuelwood species. In India the timber is used for house-building, railway sleepers, planks and scantlings, and makes a good fuelwood; one use in Nepal is for local ploughs. The wood contains a skin irritant and hence is unpopular with wood-workers.

The leaves are used for fodder, though it is not one of the best fodder species. They contain about 9.6 per cent crude protein (Panday, 1982). Leaf fall is between mid-February and mid-April, and the new flush of leaves occurs almost immediately after this. Only the young newly flushed leaves are used, between April and mid-June. In fact it is often more valued for bedding than as a fodder. In the Dhading District villages studied by Upadhyay (1991) it was a relatively unimportant fodder species, and often more valued as a multipurpose species (timber and bedding) than as fodder. In Dolakha District it was fairly plentiful on farmers' land, amounting to eight per cent by number of trees on this type of land. It was not popular among farmers, and very few would consider planting it. It was not included in the list of species used for fodder in southern Lalitpur District (Upton, 1990) though it must certainly occur there, and in addition was planted there by local farmers (Hausler, 1990). Neither was it included in the fodder trees in Lamjung District (K.P. Gajurel *et al.*, 1987).

The young plants, leaves and roots are used medicinally, against fevers, and the bark is anthelmintic and rubefacient. The Department of Medicinal Plants (1970) estimates an annual export of *Schima* products for medicinal use of about 1500 *maund* (about 60 t).

Importance in Nepal

Schima has been grown in a number of nurseries mostly for issue to farmers, and it has also been used in community forestry plantations. However its main importance is not as a plantation species, but as a constituent of the natural forest. There is much degraded *Schima-Castanopsis* forest in Nepal which, if given protection, is capable of re-establishing itself quite rapidly. Also, as

mentioned above, natural regeneration, from coppice and seed, is found in plantations of other species, particularly *Pinus roxburghii*.

If the main object of management of these plantations is to grow pine wood timber then the *Schima* is a serious competitor to the *Pinus* species and will need to be kept in check. However if the object is to provide fuel and fodder for local use this invasion by *Schima* is to be welcomed as it will increase the total biomass of the plantations and also provide material of greater value to the local people than *Pinus* wood. Certainly the planting of *Schima* seedlings in cut-over or degraded *Schima* forest is usually pointless, as adequate regrowth in these areas will normally be obtained naturally. The only circumstances in which planting seedlings in such areas would be justified is to fill in blanks which were not regenerating satisfactorily.

References: M.W. Campbell (1983a); Choudhury and Ghosh (1958); Forestry Research Institute (1975); Gamble (1922); Ghosh (1977); Kessler (1981); Lamichhaney and Joshi (1980); Mader and Stewart (1983); Panday (1982).

Sesbania Adans.

Papilionaceae

Herbs, shrubs or short-lived trees. Leaves pinnate with an even number of narrow leaflets, the rachis ending in a small point. Flowers rather large, in axillary racemes. Pods long and narrow, with numerous seeds separated by transverse partitions. *Sesbania* species are fast-growing, soft-wooded, short-lived trees which have been suggested as multipurpose fuelwood, fodder and food trees. They fix nitrogen. The three species described below are tropical plants, cultivated in the Terai of Nepal. All are palatable to cattle and require good protection against grazing when young. In Nepal their main potential would be as multipurpose trees in the Terai. They could be regarded as possible alternatives to *Leucaena leucocephala*. The seed, after being treated in hot water, should be sown directly into containers. Growth in the nursery is rapid, and seeds sown in March or April should give plantable stock by the monsoon. Direct sowing of the seed in plantations is also possible. Plantations should be restricted to altitudes below 1000 m as the trees are not frost-resistant.

***Sesbania bispinosa* (Jacq.) W.F. Wight**

(Syn. *S. aculeata* (Willd.) Poir.)

Branches and leaf rachises often armed with small weak prickles. Leaves up to 30 cm long, with 20–40 pairs of leaflets. Racemes with 3–6 flowers, 9–12 mm across, pale yellow. Pod 15–22 cm long by 3 mm thick, not constricted between the seeds. Usually shrubby, but some forms may grow to a height of 4 m. It is capable of growing on wet, almost waterlogged soils, and is also said to be capable of suppressing *Imperata*. The wood is light (300 kg m^{-3}) but the rapid growth of the tree makes it a high volume producer; in Italy 15 t ha^{-1} , bone-dry, have been produced per annum. It has been suggested that it could be grown on extremely short rotations (six months to one year) as a source of pulpwood. The seed contains a gum which could be used as a substitute for guar gum from *Cyamopsis tetragonoloba*. Up to $1500 \text{ kg of seed ha}^{-1}$ have been reported, with a gum content of 30–42 per cent. (It is probable that these high yields of seed and wood are from irrigated plantations.) The stems yield a bast fibre suitable for sacks and cordage.

References: National Academy of Sciences (1979; 1980).

***Sesbania grandiflora* (L.) Poir.**

(Syn. *Agati grandiflora* (L.) Desv.)

Nepali: agasthi.

Unarmed. Leaves up to 30 cm long with 10–30 pairs of leaflets. Racemes with 2–4 flowers; flowers up to 8 cm across, red or white. Pod 25–30 cm long by 8 mm broad, four-angled. This species is capable of growing into a tree 10 m tall with a stem 30 cm in diameter. It is reported to be tolerant of a wide range of soil types. On favourable sites trees have reached a height of 8 m and a diameter of 10 cm in three years, and an annual increment of $20\text{--}25 \text{ m}^3 \text{ ha}^{-1}$ can be expected. The wood is soft and light, about 420 kg m^{-3} . It is not durable, but is used for small poles. It is a possible source of paper pulp. Young leaves, flowers, and fruits are eaten in the Terai (Regmi, 1982). The leaves are an excellent fodder, reported to contain over 36 per cent of crude protein, which, if correct, is very high indeed. The seed ripens in October to November, and can be stored without difficulty. There are about 17,000 viable seeds kg^{-1} . At Shankarnagar in the Terai (140 m) after 17 months there was 32 per cent survival with a mean height of 4.4 m. The trial was abandoned due to shoot-borer attack. Plants from northern Australia are sometimes distinguished as *S.*

formosa. This was included in the same trial, where it had 72 per cent survival with a mean height of 5.4 m; it was also affected by shoot borer.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); National Academy of Sciences (1979); Webb *et al.* (1984).

***Sesbania sesban* (L.) Merrill**

(Syn. *S. aegyptiaca* Pers.)

Leaves 7–15 cm long, with 9–20 pairs of leaflets. Racemes with 3–10 flowers, which are yellow more or less mixed with purple and 3–7 cm across. Pods 9–22 cm long, constricted between the seeds. It grows to 6 m in height, or more, and height growth of 5 m in 12 months has been reported. The tree will grow under a wide range of soil conditions, including both acid and alkaline soils. It will withstand periodic flooding. The wood weighs about 430 kg m⁻³. The stems are used for roofing poles. Flowers and young leaves are eaten, and the seeds, after soaking for three days to remove a toxic principle, have been used as a famine food. There are about 58,000 clean viable seeds kg⁻¹. The seed ripens in September to October, and can be stored for at least two years. In the trial at Shankarnagar referred to above, at 17 months there was 92 per cent survival with a mean height of 5.3 m.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); National Academy of Sciences (1983a).

***Shorea* Roxb. ex Gaertn.**

Dipterocarpaceae

***Shorea robusta* Gaertn.**

Nepali: sal, agrath, sakhuwa.

Large tree. Leaves glabrous, ovate-oblong, 10–20 cm by 6–12 cm; apex a blunt point, base cordate; 12–14 pairs of lateral veins; stalks 2–2.5 cm long. Flowers yellow, about 2 cm across, in large showy branched clusters. Fruit ovoid, about 8 mm in diameter, with five wings, three long and two short, the longer up to 7.5 cm long.

Natural occurrence

Shorea robusta forest is dominant in the Bhabar Terai, except in areas of very high rainfall, where it is replaced by mixed forest, and along streams. It also covers most of the Siwalik Hills, and the duns between them. Along river valleys it penetrates deep into the midlands, along the lower slopes of the hills, sometimes up to 80 km from the plains. Its maximum altitude is about 1500 m, but it is not common above 1000 m. A number of different types of *Shorea robusta* forest have been distinguished; Dobremez (1976) lists nine, and Champion and Seth (1968a) more, many of which can be expected to be found in Nepal. However for the present purposes it is sufficient, following Stainton (1972), to distinguish the Bhabar Terai and Terai *S. robusta* forests from the hill *S. robusta* forest which includes the forest along river valleys in the midlands. In the former the trees are much larger and the species composition richer, while in the latter the trees rarely exceed 15 m in height. At its upper limits it is replaced by *Pinus roxburghii* or *Schima-Castanopsis* forests.

Silvicultural characteristics

A large tree, exceptionally reaching a height of 45 m. It is deciduous but only for a short time in the year, except in very dry localities. It is a light-demander. It grows on a wide range of soil types, except in the very sandy, gravelly soils immediately adjoining rivers in the Bhabar Terai zone, where it is replaced by *Dalbergia sissoo* and *Acacia catechu*, and in waterlogged areas. It grows badly on stiff clays. It has been reported to avoid limestone areas, but this appears to be due to the dry soil often formed over limestone, as it grows quite well on soil containing limestone debris. The seedlings will tolerate some frost, but not annual heavy frosts such as occur in frost hollows. However in most of the *S. robusta* areas of Nepal frost is rare.

Seedlings exposed to unfavourable conditions, such as frost, drought and fire, frequently dieback. In nature many die completely, but in others the root remains alive and continues to send up new shoots each year, until eventually a very strong rootstock develops which produces a shoot which continues to grow and eventually forms a tree. This process may take 3–10 years. However this annual dieback is by no means universal, and under good conditions the seedlings will produce a shoot which will continue to grow without dying back.

This capability of the seedlings and young plants to shoot after having been cut back contributes to the remarkable ability of cut-over *S. robusta* forest to regenerate. On land which was previously *S. robusta* forest and cleared for cultivation, if the cultivation is abandoned after a few years, and the site is then protected against grazing, there will often be found, within a year, very numerous young *S. robusta* shoots of uniform height, arising from roots which

have survived in the ground. This will not happen if the land has been cultivated too long, or heavy grazing takes place. This behaviour of the seedlings causes them to be considerably resistant to fire, as they may be burnt back annually for many years and shoot from the base annually, until eventually a stem is established. Older trees are also very resistant to fire. Young seedlings are very liable to damage by browsing, and in heavily grazed areas may be completely eliminated. Older *S. robusta* trees coppice well in most localities, but not if the stems are more than 20–30 cm in diameter. Coppicing should be completed before the onset of the hot season.

Shorea robusta is not usually severely affected by disease, but M. Karki (1992) records complete destruction of an area of forest at Hetauda by the root rot fungus, *Polyporus shoreae*.

Natural regeneration

The fruit ripens at the beginning of the rains, usually in June, and the propellor-like action of the wings may carry the seed up to 100 m from the mother tree, more in strong winds. Provided that there is rain soon after the seed falls germination will begin almost immediately; if there is no rain the seeds will die. About one year in three is a good seed year, and one in four moderate; the rest are poor. If the seed falls on a layer of dead leaves it may germinate, but often the root will fail to penetrate through the leaves and the seedling will die. On bare soil, such as is produced by fire, germination and establishment is more satisfactory. Best development is where there is full overhead light but light side shade. Regeneration is plentiful in most *S. robusta* areas, provided they are protected against grazing, but much comes from coppice and growth of seedlings which have died back in previous years, as described previously.

Artificial regeneration

The seed ripens in June. When ripe the fruits are pale green in colour, and the wings dry and brown; they can easily be detached from the branches by lightly shaking the trees. The most fertile seed is reported to be produced about the middle of the fruiting season. Germination is hypogeal; it is rapid, and often begins when the fruits are still on the tree. There are between 450 and 1000 fruits kg⁻¹.

The seed loses its viability very rapidly and should be sown within a week after collection. Packing in lime is reported to have produced 45 per cent germination of seed 27 days old, as compared to an initial germination percentage of 90. Drying out of the seed causes rapid loss of viability, so keeping it moist may help to prolong viability a little. In general however the seed cannot be stored (Anon., 1983b).

In India for direct sowing under taungya, strips are hoed about 30 cm wide, separated from the taungya crop by uncultivated strips also 30 cm wide. Regular weeding of the seedlings in the lines is necessary during the first and second years, and in the second and third year the seedlings need to be thinned out.

For raising nursery plants the seed should be sown directly into containers, two seeds per container, in June. No shade should normally be needed, but frequent root pruning is necessary as the species develops a strong taproot. Such seedlings will be ready for planting by the next monsoon. The use of stumps is still at a trial stage. Bare-root plants have no chance of survival.

Rate of growth

Under very favourable conditions initial growth can be quite fast, with a height of 6 m after five years from seed. This, however is exceptional. In a planted plot at Adabhar at the age of 3.5 years mean height was 1.95 m, but there were only 46 per cent survival. In natural regeneration at Sagarnath, age 33 months, mean height was 3.5 m and dbh 1.2 cm. Selected trees such as might eventually have grown to maturity averaged 4.6 m in height by 2.1 cm in diameter. There were 4575 *S. robusta* trees and 1750 trees of other species ha⁻¹ (K.J. White, 1988b). In another area of natural regrowth at Sagarnath, estimated age 14 years, the following data was obtained (Table 60).

Table 60—Natural regrowth of *Shorea robusta* mixed with other species aged 14 years

Species	Stems per hectare	Mean height (m)	Mean diameter (cm)	Volume overbark (m ³ ha ⁻¹)	MAI overbark (m ³ ha ⁻¹)
<i>Shorea robusta</i>	928	8.5	9.1	28.8	2.06
other species	711	8.8	9.1	21.3	1.52
total	1639	8.6	9.1	50.1	3.58

In the Tinau watershed area an area containing *S. robusta* was protected from grazing when the trees were knee high. After three years the mean height was 2.5 m, dbh 2.2 cm, and the average green weight per tree 2.9 kg. The total tree biomass was 53 t ha⁻¹, of which *S. robusta* was 97 per cent (Fonzen, 1986a). For timber production in India the rotation is from 100 to 120 years. Table 61 is taken from Indian yield tables (Griffith and Sant Ram, 1943). Volume tables for *S. robusta* have been prepared by E.R. Sharma and Pukkala (1990).

Table 61—Growth of *Shorea robusta* from Indian yield tables

Age	Quality I			Quality IV		
	Height (m)	dbh (cm)	MAI (m ³ ha ⁻¹ yr ⁻¹)	Height (m)	dbh (cm)	MAI (m ³ ha ⁻¹ yr ⁻¹)
10	—	8.1	2.8	—	4.6	0.1
20	14.9	14.2	4.5	7.0	7.4	0.8
50	25.9	29.2	8.6	11.3	17.0	1.9
100	36.9	48.3	11.2	17.7	29.5	3.1
120	39.6	54.9	11.0	18.3	33.3	2.9

Uses

Shorea robusta timber is the main constructional timber used in Kathmandu. It is strong and elastic, and the heartwood is very durable. It has, however, the disadvantages of being difficult to season, and to plane, as it is cross-grained. It is used for construction, doors, window frames, planking, carts and carving. At one time there was considerable export of *S. robusta* logs to India for railway sleepers and other purposes. This was a very old practice; Hooker, in 1848, noted that *S. robusta* logs were floated to Calcutta from the eastern Terai (Hooker, 1891). The timber weighs between 800 and 960 kg m⁻³. It is an excellent fuelwood, with an energy content of about 22,700 kJ kg⁻¹ for the heartwood, and 21,300 kJ kg⁻¹ for the sapwood. It also makes a good charcoal. The leaves are lopped for fodder, though they are of only medium quality. They contain about 10 per cent crude protein and the total digestible nutrients are 43 per cent. The leaves are also widely used for temporary plates. The seeds produce an oil which sets hard and white in cold weather and nowadays is extracted commercially on a considerable scale. It is used as a substitute for cocoa butter, among other purposes. After extraction of the oil the cake can be used to supplement cattle feed. From 1984 to 1986 production averaged about 430,000 l of seed oil plus 3500 t of de-oiled cake.

Importance in Nepal

The natural *S. robusta* forests in the Terai are the country's main source of building timber, and in the valleys of the hill region are a valuable source of timber, fuelwood, and fodder. Unfortunately in both these areas the *S. robusta* forests are wasting assets. In the plains their area is being continuously reduced by conversion to agriculture, legally or illegally, and little is being done to

ensure regeneration. In the hills lopping and excessive cutting for fuelwood have reduced much of the *S. robusta* forest to degraded scrub.

Rather than establishing plantations of *S. robusta*, the most urgent task is to rehabilitate the existing forests. In the hills especially they respond dramatically to protection for a few years, and management of such forests by regular coppicing would not be difficult, and would produce a useful yield of fuelwood and poles. Some such forests have been seen which were heavily overstocked; a thinning in such areas would both produce a yield and also improve the growth of the remaining trees.

In India, artificial regeneration of *S. robusta* is used primarily to supplement natural regeneration of managed forests, which is sometimes difficult to obtain. The method used is mainly direct sowing under taungya, with nursery stock used to replace failures in the sown areas. In Nepal also any artificial regeneration should be confined to areas of *S. robusta* forest where natural regeneration is deficient. Up to the present *S. robusta* has scarcely been raised at all in Nepalese nurseries.

References: The revised edition of *Troup's Silviculture of Indian Trees* (H.B. Joshi, 1980) with 427 references, has a very full account of *S. robusta*. Other references: M.W. Campbell (1983a); Choudhury and Ghosh (1958); Gamble (1922); Ghosh (1977); Letourneux (1957); Magini and Tulstrup (1955); Panday (1982); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

Syzygium Gaertn.

Myrtaceae

Syzygium cumini (L.) Skeels

(Syn. *Eugenia jambolana* Lam.)

Nepali: jamun, ban jamun, kalo jamun, jambu, kyarnuro, phanir, kainyu.

Tree with light grey bark. Leaves opposite, smooth, shiny, with numerous straight parallel veins. Flowers white in small rounded clusters at the ends of the inflorescence branches, stamens protruding. Fruit 12–30 mm long, dark purple.

Occurrence

Widespread in Nepal from the Terai to about 1600 m in a wide range of vegetation types including *Shorea robusta* forest (both Bhabar Terai and hill-

side types), tropical and subtropical evergreen forests, and *Schima-Castanopsis* forest. In the Terai it is often gregarious along streams and in swampy places.

Silvicultural characteristics

It is shade-tolerant, particularly when young. It prefers clay loam soils, but will grow on sandy alluvial soils near rivers; it is not suitable for dry sandy or gravelly soils or stiff clays. In general a fair amount of soil moisture appears to be necessary for satisfactory growth. The seedlings are susceptible to frost damage, but older trees will withstand abnormal frosts. It coppices very freely even from large stumps. It is readily browsed.

Artificial regeneration

The seed ripens between June and August; there are from 1000 to 1300 seeds kg^{-1} . Sometimes there may be 2–5 seeds forming the fruit stone, compressed together to resemble a single seed and held together by a leathery covering. In such cases several seedlings may emerge from one so-called seed. The seed loses its viability within 2–3 months, and should be sown immediately after it has been collected. It is sown into polypots at the rate of two per pot. Germination is rapid and should be completed within 2–3 weeks. The seedlings should be shaded when young, and regularly watered, as they are very sensitive to heat and drought. They will require a year in the nursery. Direct sowing of the seed is only successful under shade. Stumps from two-year-old plants, grown in beds which are not irrigated during the dry season, have been used in India. There large transplants up to 150 cm tall, and with balls of earth round their roots, are also used.

Performance in plantations and rate of growth

The only records seen from Nepal trial plots were from Butwal (140 m) where trees 18 months old averaged 1.7 m in height, and those 30 months old (another trial) 2.5 m. In both trials height growth was nearly the lowest of all species in the trial. Survival was good (Neil, 1990d). In Uttar Pradesh, in India, trees in natural forest have a mean diameter of 8.7 cm and a height of 7.7 m at the age of ten years, and 17.6 cm diameter and 11.3 m height at the age of 20 years. Survival in 1983/84 community forestry plantations averaged 39 per cent. The average altitude of the plantations was about 1500 m, perhaps a little high for this species (Ghimire and Nielsen, 1985).

Uses

The wood is reddish-grey, rough and moderately hard. It weighs about 770 kg m^{-3} , and has a calorific value of about 20,100 kJ kg^{-1} . It is a very good fuelwood.

It is durable and in India is used for posts, beams, rafters, agricultural implements and carts. The leaves are lopped for fodder, though only on a small scale in Nepal. The crude protein content is rather low, 7.9 per cent according to Panday (1982). R.V. Singh (1982) reports crude protein content ranging from 7.6 to 10.8 per cent. The digestibility of the crude protein is very low, only one per cent, due to the high tannin content of the leaves. They are thus a relatively poor fodder. The seed also is edible by cattle and can be used to replace a proportion of oil cake in animal feed. The pulp of the fruit is sweet and astringent, and is eaten by humans. There are improved varieties with larger fruits than the wild plants have.

Importance in Nepal

Syzygium cumini has been included in community forestry plantations, but not on a very large scale; about 12,000 trees were planted in 1983/84. In the Terai people plant it near their houses, and also as avenue trees (Regmi, 1982). In plantations it is most likely to be of value in the Terai, particularly on swampy grounds, and near streams, but as the data from Butwal show, growth is likely to be slow.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhancy and Joshi (1980); Magini and Tulstrup (1955); National Academy of Sciences (1980); Panday (1982); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

Syzygium jambos (L.) Alston, the rose apple (gulab jamun) is cultivated in the Terai for its fruit.

Taxus L.

Taxaceae

Yew

Taxus baccata L. subsp. *wallichiana* (Zucc.) Pilger

(Syn. *Taxus wallichiana* Zucc.; *Taxus baccata* L. of older Indian literature)

Nepali: barme salle, dhengra salla.

Tree; bark thin, reddish-grey, peeling off in narrow strips. Leaves in two rows, 1.5–2.8 cm by about 2 mm, dark green above, pale beneath. Seed surrounded by a red fleshy aril, looking like a berry, about 7 mm in diameter. The Himalayan

yew is found in Nepal between 2300 and 4400 m, often as an understorey tree. It is particularly characteristic of *Abies spectabilis* forest, especially on limestone, but is found associated with *Picea smithiana*, *Tsuga dumosa*, *Pinus wallichiana* and *Quercus semecarpifolia*, particularly at higher altitudes. It extends into the rather dry inner valleys of the Humla-Jumla area, for example at Lake Rara and Simikot. It is a strongly shade-tolerant evergreen tree, sometimes reaching a large size; heights of over 30 m and diameters of nearly 2 m have been recorded.

The seed, contained in a bright red berry-like fruit, ripens in November. There are about 8000 seeds kg⁻¹, and they can be stored for several years in tins in cold storage. After the seed has been removed from the pulp it should be stratified in sand over winter, in a cool place, and sown directly into polythene pots in the following spring. Germination often takes a long time, and growth is slow, so that the seedlings will need two years or more in the nursery before they can be planted out. *Taxus baccata* can also be propagated from cuttings. Its growth is very slow. The mean diameter increment of naturally growing trees ranges from 1 to 4 mm. The tree is very long-lived.

The wood is hard, fine and even-grained, and moderately heavy (about 700 kg m⁻³). In India it is used for carrying poles, bows and furniture; wood of the European species is used for turnery and fine furniture but is very scarce. In Europe the leaves are poisonous to cattle, but in parts of the western Himalaya the trees are lopped for cattle fodder. According to Brandis (1921) green twigs are used to decorate houses in Nepal during religious festivals.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhane and Joshi (1980); Troup (1921).

***Tectona* L.f.**

Verbenaceae

***Tectona grandis* L.f.**

Nepali: sagawan (sagban).

Teak.

Large tree with a straight stem; bark pale grey, with shallow longitudinal fissures. Leaves opposite, very large, up to 60 cm long, underside densely hairy. Flowers white in erect terminal panicles. Fruit covered in felty hairs, and enclosed by the inflated calyx.

Origin

Tectona grandis is not indigenous to Nepal or northern India, but is found in the Indian peninsula, Burma, Thailand, Laos and Indonesia, though there are doubts whether it is truly indigenous in Indonesia. It has been very widely planted in tropical countries for its timber.

Silvicultural characteristics

A deciduous tree, capable on good sites of reaching a very large size. It is a pronounced light-demander and will not tolerate suppression at any stage of its growth. Its best growth is on deep well-drained loamy to sandy loam soils; it will grow on harder and shallower soils, but then its rate of growth is reduced. It is not sensitive to pH, and grows very well on soils derived from limestone, as long as they are deep enough. It does not tolerate badly drained soils.

Tectona grandis is better than some species at surviving where there is grass and weed growth, but good weeding is needed to obtain satisfactory rates of growth. Accumulation of moist weeds round young seedlings often causes them to rot. It is very resistant to fire, and even young plants when burnt generally shoot from the root. This burning back and shooting may continue for several years, while the root gradually increases in size, and eventually produces a shoot which escapes the fire. Older trees are little damaged by grass fires unless there is an accumulation of dry branches or other inflammable material near the base of the stem. The seedlings are killed by frost, and *T. grandis* should not be planted in frosty areas. It is not readily browsed, though wild pigs may do damage by rooting up the seedlings. It coppices very well even when the trees are of large size.

In plantations *T. grandis* suppresses nearly all undergrowth, leaving a bare floor with little but fallen leaves. This means that there is little ground protection, and *T. grandis* should not be planted in pure plantations on sloping erodible sites.

Artificial regeneration

Seed

In India the fruits ripen between November and January and gradually fall to the ground during the hot season. They can easily be collected from the ground since such seed is just as good, if not better, than seed collected from the tree. At present few stands in Nepal have reached the seed production stage, and most seed will need to be imported.

What is commonly referred to as seed is actually a bony drupe, enclosed in a thick felty covering, which contains 1–3, occasionally four, true seeds. The most frequent number of seeds per drupe is one only, and completely empty

drupes are common, 20–50 per cent of the total. There are between 1200 and 3100 drupes kg^{-1} , the number varying according to the provenance. They are nearly always sown intact, and no attempt is made to extract the seed. Indeed extracted seeds give much lower germination percentages than whole drupes (Suangtho, 1980). The drupes retain their viability for a long time, and may lie dormant on the forest floor for many years. They can be stored quite easily in well-aerated sacks at room temperature, but must be kept quite dry. One-year-old drupes give better germination than fresh ones.

If untreated the drupes germinate slowly and irregularly often over a period of a year or more. Thus many methods have been recommended to accelerate and improve germination. Some of these are listed by Lamichhane (1982), and his list is far from exhaustive. There is some evidence that drupes of different provenances differ in their response to differing treatments. Actually in many countries where *T. grandis* is raised on a large scale, and abundant supplies of seed are available, the technique in practice is to sow very large quantities of seed and accept low germination percentages.

Suangtho (1980) did a number of experiments on *T. grandis* seed germination at the Australian National University at Canberra. His conclusions were that good germination can be obtained by heat treatment of the seed before it is sown, either for 1–2 weeks at 50°C, or for a few hours up to 48 hours at 80°C. Soaking the seed in water during the treatment gave no advantage and was frequently harmful. Sowing in sand with a moisture content of about 11 per cent gave the best results.

Under field conditions exposure of the seed to controlled high temperatures will rarely be practicable, unless drying ovens are available. A suggested method is as follows: spread out the seed (preferably one year old) in a thin layer on hard ground or concrete in the sun, with plastic sheeting over it to increase the temperature, but keeping it dry, continuing this treatment for 4–5 weeks. Then sow the seed in sand, without shade, with the point of attachment of the fruit stalk downwards, by pushing the seed into the sand until the base is just covered. Water twice daily, giving a thorough soaking. As individual seeds germinate, prick them out into beds or plastic pots.

Nursery treatment

The commonest and most satisfactory method is to raise *T. grandis* as stumps. Seedlings are sometimes raised in polythene bags to supplement stumps, as they can be raised in 3–4 months in the nursery, whereas stumps need a year.

For raising as stumps, pre-treated seeds may be sown in beds early in the rains in drills 5–8 cm apart, with the seeds touching each other in the drills. However a better method is to use pre-germinated seed and prick them out at a

spacing of 15 cm x 30 cm in the beds. This gives ample room for the seedlings to develop; if the seed is sown in beds without being pre-germinated it often produces a very congested stand of weak seedlings. There should never be any shade, and watering is unnecessary except immediately after sowing, if there should be a dry spell, but the beds should be kept free of weeds by hoeing between the seedlings. This should produce plantable stumps 1–2 cm in diameter at the collar by the first pre-monsoon rains. Beds used for raising stumps will need either to be given artificial fertilizers, or to be rotated with a leguminous crop to maintain soil fertility.

In Thailand it is the practice to lift the plants about February, and make them into stumps with 2 cm of stem and 13 cm of root. All secondary roots are scraped off the taproot. The stumps are then tied into bundles and stored between layers of very fine dry sand in pits 1.5 m deep. A thatched shed is built over each pit, to keep it dry, and also to keep it as dark as possible. The stumps thus prepared are planted in the first rains in April. It is claimed that such stored stumps give better results than stumps lifted directly from the nursery, as when they are planted they are still dormant, whereas plants from nursery beds will already have begun to put out new leaves and are more likely to suffer damage if, for example, the rain after they have been planted is less than normal.

Seedlings may be raised in polythene pots by sowing the seed in February or March. Because of the very erratic germination of *T. grandis* seed, it is essential that pre-germinated seeds should be used, sown at one seed per pot. Such seedlings will of course need to be watered, but no shade is needed. Seedlings raised in pots are useful when, for instance, by some mischance insufficient stumps have been raised, or if there is only a short time before the planting season in which to raise nursery stock. Otherwise stumps are preferable.

Planting

The best time for planting stumps is during the pre-monsoon rains, as soon as the soil is wet to a depth of about 20 cm. If stored dormant stumps are used they can be planted at the time the pre-monsoon rains are expected. If no rain falls they will remain dormant and alive for at least 2–3 months. It is very important to plant the stumps as early in the rains as possible; delaying planting until July will mean the loss of most of the first season's growth. Container-raised seedlings should be planted with the first monsoon rains. It is not necessary to make pits before planting: a hole just large enough to take the stump is sufficient, but the soil must be well firmed round the stump. Spacing should preferably be 2 m x 2 m or 2.5 m x 2.5 m; if growth is satisfactory this will enable a first thinning to be made when the trees are aged 5–7 years. For

planting under taungya a wider spacing, say 4 m x 2 m, may be necessary to allow cultivation between the trees.

Tending and thinning

Tectona grandis will withstand a certain amount of grass and weed competition in that the plants will remain alive and gradually struggle up through them, but for a satisfactory plantation thorough weeding is necessary. If taungya cultivation is possible, this will give the best results.

If teak has been planted at 2 m x 2 m or 2.5 m x 2.5 m it can be given a first thinning when the trees are 7–10 m tall. This can be a systematic one, removing every alternate tree. In a good plantation this height should be attained by the age of about five years. Subsequent thinnings should be made at about five-year intervals during the early life of the plantation, extended to ten years as the trees grow older. Timely and regular thinning is necessary; if thinnings are delayed the trees take a long time to respond once they are thinned.

Rate of growth

Apart from very young plantations, in Nepal measurements are available from only one older plantation, at Sagarnath (M.R. Joshi, 1982?). This was planted in 1971, using seed from Gorakhpur in India, on an alluvial site with a permanent water table 7 m below the surface. The original spacing was 8 ft x 8 ft (2.4 m x 2.4 m) equivalent to 1680 stems ha⁻¹. The plantation was thinned lightly when seven years old, but the volume removed was unrecorded. At 10.5 years old there were 1330 stems ha⁻¹, with a mean dbh of 14 cm, a top height (100 largest trees per hectare) of 19.3 m, a basal area of 22.1 m² ha⁻¹, and a volume over bark (to 5 cm top) of 152.5 m³ ha⁻¹. This is equivalent to a mean annual increment of 14.5 m³ ha⁻¹, excluding the thinning at seven years old.

These growth rates are equivalent to Quality II in Laurie and Ram's yield tables (1940) but the highest quality in these tables is mostly from Burma. They fall within Quality I of the tables for Nilambur teak in Kerala, India, (Troup, 1921). Hence the growth rates in this plantation are very satisfactory, though admittedly it is on an unusually good site. It demonstrates that high quality *T. grandis* plantations can be grown in Nepal on certain sites. A little information is available from younger trials. In the Tamagardhi taungya scheme, Bara District, the following growth figures (Table 62) were obtained (B. Shrestha and Pandey, 1989). For plantations raised under taungya these results are poor. In another plot at Sagarnath trees five years old had a mean height of 7.6 m and a mean dbh of 4.7 cm (K.J. White, 1988b). This is about equivalent to Quality III of Nilambur teak, with, as far as can be estimated from this very early growth, an eventual mean annual increment of between 4 and 5 m³ ha⁻¹.

Table 62—Growth of *Tectona grandis* at Tamagardhi

Age (yr)	Mean height (m)	Mean dbh (cm)
1	0.3	0.3
2	0.7	0.6
3	1.2	0.9
4	1.8	1.1

The mean annual increment of *T. grandis* in India is mostly between 4 and 8 m³ ha⁻¹. For timber production the rotation on good sites is likely to be between 60 and 80 years, but on poorer sites it may be much longer. For more details on growth in India see Laurie and Ram's (1940) yield tables.

Uses

Tectona grandis timber is world famous and is in high demand on world markets, being ornamental, durable, and relatively easy to work. Previously in places where *T. grandis* was abundant it was very widely used for all types of house-building, ships and boats, furniture and even railway sleepers, but nowadays, as *T. grandis* is becoming increasingly scarce and high in price, there is a tendency to use it for higher value products such as veneers, rather than for general construction work. It weighs about 720 kg m⁻³.

It is an excellent fuel, and in the 1920s and 1930s teak plantations in parts of Africa were managed on a coppice rotation for fuelwood production. However in view of the high value of its timber this practice has now been largely abandoned. Although the heartwood is extremely durable, the sapwood is not, and in some places is very susceptible to attack by powder post beetles. This limits the use of small poles for some purposes.

Importance in Nepal

Some plantations have been established in the Bhabar Terai and Terai zones; at least one is of excellent quality, but others are rather disappointing. This may be due to unsuitable sites, to poor tending, or a combination of both. It does appear, however, that good *T. grandis* sites are not very common. The main need in the Terai is for fuelwood and for this purpose there are certainly species which will produce a higher yield than *T. grandis*. However, there is also a national demand for high quality timber, met at the moment largely by *Shorea robusta*, but supplies of this are dwindling. In areas where suitable sites can be found and since good *T. grandis* soils are often good agricultural soils, there may be difficulties there would seem to be a case for at least a small-scale

programme of *T. grandis* plantations. It should also be borne in mind that a third grade *T. grandis* plantation may be more profitable than a first grade plantation of a less valuable species. However there does seem to be a need for more discrimination in deciding on which sites *T. grandis* should be planted.

References: The literature on *T. grandis* is copious; two bibliographies exist, Krishna Murthy (1975) and K.B.L. Mathur (1973). Other references: M.W. Campbell (1983a); Champion and Brasnett (1958); J. Evans (1982); Gamble (1922); Ghosh (1977); P.K. Gupta *et al.* (1980); Khanal (1975); Lamichhane and Joshi (1980); Letourneux (1957); Magini and Tulstrup (1955); Nepal (1986); Streets (1962); Troup (1921); Webb *et al.* (1984).

Terminalia L.

Combretaceae

Trees. Leaves alternate or nearly opposite. Flowers small, sessile, greenish or white, usually in long spikes. Calyx tube constricted above the ovary. Petals none, stamens ten.

Key to the species

- (1) Fruits winged 2
- (1) Fruits not winged 3
- (2) Fruits about 0.4 cm long, with two wings; leaves glabrous, with numerous parallel veins *T. myriocarpa*
- (2) Fruits over 2 cm long, with 5–7 wings 4
- (3) Branchlets and young leaves clothed with short rust-coloured hairs; fruit 3.5–5 cm long, with five thin wings over 1 cm broad wings *T. alata*
- (3) Branches and young leaves glabrous; fruit about 2.5 cm long, with 5–7 narrow wings about 6 mm broad *T. arjuna*
- (4) Fruit grey velvety, ovoid, 2.5 cm long; leaves clustered at ends of branches, base tapering into long leafstalk (more than 3.5 cm) *T. bellirica*
- (4) Fruit glabrous 5
- (5) Fruit bluntly five-angled, 2.5–3.8 cm long; leaves not clustered at branch ends, base wedge-shaped, stalk 1.2–2.5 cm long *T. chebula*

(5) Fruit flattened, with a keel at each side, about 5 cm long; leaves clustered towards branch ends, obovate, base rounded or cordate, stalk 0.6–1.2 cm long; planted tree *T. catappa*

***Terminalia alata* Heyne ex Roth**

(Syn. *T. tomentosa* (Roxb.) Wight & Arn.)

Nepali: asna, saj.

Trade name: Indian laurel.

Occurrence in Nepal

Between 200 and 1400 m, usually associated with *Shorea robusta*, but occasionally forming almost pure forests.

Silvicultural characteristics

A large deciduous tree over 30 m tall by 1.4 m diameter. The seedlings can withstand moderate side shade, but are killed by more than one year of heavy overhead shade. The tree grows best on deep alluvial soil, but tolerates stiff clays, and is found round the edges of swamps where it can withstand a good deal of waterlogging. Its growth on poor shallow soil is stunted. It also does badly on freely draining sands where the water table is deep. It is found naturally on soils with pH ranging up to 8.4. The seedlings are often killed back by frost, but will sometimes shoot again from the base. They are less liable to grazing damage than some other species, as they are leafless during the hot season. The tree is fairly tolerant to fire damage. It coppices well up to about 40 cm in diameter, but above this size the coppicing ability is low. It pollards well.

Natural regeneration

The fruit is spread partly by wind, and partly by water. The seedlings can establish themselves to some extent if the seed falls on a layer of dead leaves, but establishment is best on loose soil free from dense weed growth. These conditions are often found on new alluvial soil near rivers, but *T. alata* regeneration is by no means confined to such areas. The seedlings need full overhead light for good development; though the seed will germinate under shade, the seedlings rarely survive more than a year in such conditions. Where *Shorea robusta* and *T. alata* occur together, the *S. robusta* tends to dominate except on low, badly drained soil which the *T. alata* tolerates better.

Artificial regeneration

The fruit ripens between February and April, when it turns dark brown. It should be collected from the tree and not from the ground. There are between

400 and 700 fruits kg⁻¹. The seed can be stored for a year without serious loss of viability. Germination is reported as being between 40 and 70 per cent, but in the two nurseries from which data have been recorded in Nepal germination was nil and about 1.5 per cent respectively. This may have been due to collection of seed from the ground, as immature seed of low viability often falls prematurely from the branches. In Bihar and Orissa the seed is piled in heaps and watered daily. When it germinates it is pricked out (Ghosh, 1977). *Terminalia alata* is usually planted as stumps; for this purpose 12–15 months in the nursery will be needed. Shade is needed while the seedlings are young. For raising plants in containers 3–4 months are needed.

Performance in plantations and rate of growth

In a trial plot at Butwal (140 m) aged 2.5 years, survival was 50 per cent, mean height 3.8 m and mean dbh 4.3 cm. Growth was considerably less than that of the faster-growing exotics, and also of such species as *Dalbergia sissoo* and *Acacia catechu*. Generally growth rates in this trial have been very good. In natural forest mean annual diameter increment ranges from about 2.5 to 6 mm. Volume and biomass equations and tables are included in E.R. Sharma and Pukkala (1990a; 1990b).

Uses

The heartwood is light to dark brown, often with darker streaks. It is heavy, from 800 to 1100 kg m⁻³ and is strong, hard and fairly durable. In India it is used for joists, doors, window frames, carts, ploughs and rice pounders. It can also be used for furniture and parquet, and Nepal timber has been tested for plywood (P.C. Gupta and Bist, 1980). It has been described as an excellent timber for match splints (Dey and Ramaswami, 1960). The poles are used for house-building. It is an excellent fuel, with a calorific value of 21,000 kJ kg⁻¹ and makes good charcoal.

The leaves are used as fodder. Leaf fall is in the spring dry period, between mid-February and mid-April, and the new leaves appear before the monsoon, from mid-April onwards. The leaves have a crude protein content of 4–14 per cent, but according to R.V. Singh (1982) the digestibility coefficient of the protein is nil; hence the leaves are not very nutritious, being equivalent only to hay or straw. However, Panday (1982) considers it as a potentially valuable fodder tree for low altitudes, and it is used for fodder to a fair extent. In the villages in Dhading District studied by Upadhyay (1991) it was the second choice in species from forest land, but fodder from forest land in this area is of only minor importance. The altitudes of these villages are from 1000 m upwards. In south Lalitpur District it was only used on south-facing slopes at

altitudes below 1000 m, especially in February. Some farmers say that feeding the leaves in the pre-monsoon and monsoon seasons can cause health hazards (Upadhyay, 1991).

Importance in Nepal

It has not been planted very much, and in the few nurseries where it has been tried results have been very poor. It might have a place in afforesting stiff clay and waterlogged sites in the Terai, as it is a good species for fuelwood and poles. Growth rates, however, are rather low. It is a valuable species from the natural forest.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Indian Timbers (1968b); Lamichhaney and Joshi (1980); Letourneux (1957); Magini and Tulstrup (1955); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

***Terminalia arjuna* Bedd.**

Nepali: arjun.

This species is not included in the British Museum's Enumeration, but it is found in the sub-Himalayan tract in India and may well occur in the Nepal Terai, especially along stream banks. It needs wetter conditions than *T. alata* does. There are 175–450 seeds kg⁻¹. Germination is improved by soaking the fruit in water for 48 hours, or by hot water treatment. It can be planted as seedlings or stumps, and in India it is sometimes propagated by using large transplants with a ball of earth round the roots. It was included in the trial plot at Butwal (140 m) where at the age of 2.5 years there was 100 per cent survival with a mean height of 4.0 m and a mean dbh of 3.9 cm; better than *T. alata*. The wood (940 kg m⁻³) is used for agricultural implements and the bark as a tonic. It produces a medium quality fodder, with a crude protein content of 8.9–11.4 per cent.

References: Gamble (1922); Ghosh (1977); Magini and Tulstrup (1955); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

***Terminalia bellirica* (Gaertn.) Roxb.**

(Syn. *T. belerica* auct.)

Nepali: barro (barhu).

Occurrence

It occurs widely in tropical and subtropical forest up to about 1100 m, often associated with *Shorea robusta*.

Silvicultural characteristics

A large deciduous tree. The seedlings withstand fairly dense shade during the first year or two, but after this are suppressed and killed by heavy shade. It needs soil with a good moisture supply. Ordinary frosts do not kill back the seedlings, but severe abnormal frosts do considerable damage. It coppices fairly well, but pollards badly.

Nursery and plantation techniques

The fruits ripen between November and February, and there are about 60 fruits kg⁻¹. After the pulp is removed there are 400–520 seeds kg⁻¹. The seeds can be stored (after removal of the pulp) for about a year, but with some loss of vitality. The seed should be soaked in water before it is sown. Seed sown in February–March in polypots will produce plantable seedlings by the monsoon. The species can also be raised from one-year-old stumps.

Rate of growth

At Butwal (140 m) in a plot 2.5 years old, there was 83 per cent survival with a mean height of 2.5 m and a mean dbh of 2.3 cm; it was the slowest-growing tree in the trial. In India however growth is reported to be moderate to fairly rapid. A tree at Chota Nagpur reached a height of 11 m and a diameter of 20 cm in 16 years.

Uses

The wood weighs about 770 kg m⁻³. In India it is used for planking and packing cases, and sometimes for building, but it is not a good building material. The leaves are lopped for fodder, and contain between 8.6–17.2 per cent crude protein; they have a fairly high tannin content (6.4 per cent). They are used in Nepal to a limited extent, for instance they are recorded as fodder trees from Lamjung and Dhading Districts, but are only of minor importance there. According to K.P. Gajurel *et al.* (1987), one tree will produce about 34 kg fresh weight fodder annually. The fruits are used in ayurvedic medicine, and locally to cure coughs. They are also a source of tannin. About 10 t are collected

annually (Manandhar, 1980). The kernels are eaten, but are said to contain a narcotic principle. The fruit is used to increase the potency of local liquors (Regmi, 1982).

Importance in Nepal

It has not been planted to any great extent, except perhaps by individuals. It might be useful as a multipurpose tree in the Terai.

References: Gamble (1922); Ghosh (1977); Lamichhane and Joshi (1980); Magini and Tulstrup (1955); Rao and Purkayastha (1972); R. V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921).

***Terminalia catappa* L.**

Nepali: kathiya badam.
Indian almond.

A native of tropical littoral forests, which has been planted, especially in the Terai, as an orchard and avenue tree. There are about 24 fruits, and 800–900 seeds kg⁻¹. The seed can be stored for a year after the pulp of the fruit has been removed. Germination is easy. No growth records are available from Nepal. Elsewhere under favourable conditions growth can be fairly rapid, sometimes reaching 6 m in three years. Ten-year-old plantations are expected to produce between 22 and 36 t ha⁻¹ of wood. The wood weighs about 590 kg m⁻³ and is used for furniture, general construction, and other purposes, though it is rather difficult to work. It is a good fuelwood. The fruit kernels are edible and produce an oil used in cooking.

References: Gamble (1922); Magini and Tulstrup (1955); National Academy of Sciences (1980); Streets (1962); Troup (1921).

***Terminalia chebula* Retz.**

Nepali: harro, jangali harro, thulo harro.

Occurrence

In Nepal up to 1100 m, associated with *Shorea robusta* or with other species of *Terminalia*.

Silvicultural characteristics

A medium-sized to large deciduous tree. It is a light-demander, but young seedlings benefit from light shade. It is fairly frost-hardy, withstands fire well, and recovers well after burning. It coppices fairly well.

Nursery and plantation techniques

The fruits ripen between November and March; 140–220 dry fruits and about 540 clean dry nuts weigh 1 kg. They should be collected from the ground as soon as they fall, and not from the trees, and dried thoroughly in the sun, after which the hardened fleshy covering is removed. Seed stored for 1–2 years germinates better than fresh seed. Soaking in water for 48 hours improves germination. The seed can be sown in beds for stump production after one year in the nursery; or the seedlings can be pricked out into containers.

Rate of growth

Slow to moderate. Mean annual diameter increment of natural trees 0.5 to 0.8 cm.

Uses

The wood is used in India for furniture, carts, agricultural implements and house-building. It weighs about 920 kg m⁻³. The leaves are a medium-quality fodder, with 10.8–14.3 per cent crude protein; they are used on a small scale in Lalitpur District. The fruits are the black or chebulic myrobalans, and at one time were exported from India on a large scale for tanning. In Nepal they are used to make a conserve.

Importance in Nepal

So far not much planted, but a possible multipurpose tree for the Terai.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Magini and Tulstrup (1955); Rao and Purkayastha (1972); R.V. Singh (1982); Streets (1962); Troup (1921).

***Terminalia myriocarpa* Heurck & Muell.-Arg.**

Nepali: pani saj.

A large evergreen tree found in east and central Nepal, typically in moist situations near streams; it grows up to altitudes of about 1500 m. The seed ripens in January and February; there are about 30,000 seeds kg⁻¹. They can be stored for 3–4 months. Seed sown at the time of collection will produce

plantable seedlings by the monsoon. Germination is apt to be rather poor and irregular. Growth is fast, trees four years old reaching 4 m in height by 5 cm diameter. It has been used for planting in Assam, but only does well on deep rich soils in moist localities. The timber is of excellent quality, and is used for furniture, house-building, doors and windows, etc. It weighs 830 kg m⁻³ and makes a good charcoal.

References: Gamble (1922); Ghosh (1977); Magini and Tulstrup (1955); Trotter (1958); Troup (1921).

Terminalia tomentosa see *T. alata*.

Terminalia glaucescens, *T. ivorensis* A. Chev., and *T. superba* Engl. from West Africa were included in species trials at Bardia in 1975 and in the Kathmandu Valley in 1978/79. They are presumed to have failed. None is likely to be of much value in Nepal.

Toona M. Roem.

Meliaceae

Trees with aromatic bark. Leaves alternate, pinnate with an odd number of leaflets, or sometimes an even number if the terminal leaflet fails to develop. Flowers small, in much branched compound panicles. Fruit elongated, splitting when ripe into five valves with an angular column between them to which the winged seeds are attached.

Key to the species

- (1) Leaflets toothed; seeds winged at upper end only *T. serrata*
- (1) Leaflets without teeth; seeds winged at both ends 2
- (2) Stalks of leaflets slender, 5–18 mm long; fruit 18–25 mm long, smooth
..... *T. ciliata*
- (2) Stalks of leaflets usually shorter; fruit warty 3
- (3) Stalks of leaflets usually 4–8 mm long, channelled on upper surface, without hairs; fruit 15–20 cm long, dark brown to black *T. microcarpa*
- (3) Stalks of leaflets 4–5 mm long, covered in minute hairs; fruit 38–50 cm long, black *T. sureni*

***Toona ciliata* M. Roem.**

(Syn. *Cedrela toona* Roxb. ex. Rotl. and Willd.)

Nepali: tuna (tuni).

Toon.

Occurrence

It is found in Nepal from the Terai up to about 1700 m, mainly in forests near rivers and in moist localities. It is a characteristic species of Stainton's (1972) Tropical Evergreen Forest, Subtropical Evergreen Forest, and Subtropical Semi-evergreen Forest, but also occurs in other forest types.

Silvicultural characteristics

Despite its occurrence in some types of evergreen forest, it is deciduous; it grows up to 50 m tall by 1 m in diameter. In youth it is moderately shade-tolerant and young plants need protection from strong sun; older trees need full light. It grows best on well-drained, deep, rich, loamy soils, and on dry hill slopes the growth is stunted. Indeed it is a demanding species, and should only be planted on fertile sites. The seedlings are frost-hardy. The tree is sensitive to fire and will not withstand much drought. Seedlings are readily browsed. One of its major drawbacks is its susceptibility to damage by shoot borer (*Hypsipyla robusta*) (see Pests, page 733).

Natural regeneration

The seed, which is produced in copious amounts, falls after the early pre-monsoon rains or during the early monsoon. It is distributed by wind, but seed on the ground is carried by the water from the heavy rains until it lodges under bushes, walls, or similar obstacles. If there are breaks in the early rains the seed may germinate and subsequently die, but usually a good proportion of it germinates at a suitable time. Regeneration is good on deep, sandy, loam soils near rivers, and on abandoned cultivation. It can be increased by clearing the ground near seed bearers.

Artificial regeneration

The light, winged seeds are contained in capsules which ripen between April and June. The capsules must be collected from the tree before they open and scatter the seed, which is dispersed over large distances by the wind. As the tree tends to have a straight, tall, branchless stem, climbing it to collect seed is rather difficult. There are between 125,000 and 589,000 seeds kg⁻¹, the average being about 350,000. Published accounts on its viability vary; it has been recorded that dry seed can be stored for a year in sealed tins, but other sources

report 50 per cent loss of viability in ten weeks. The discrepancies may be due to different storage methods. As there are uncertainties about the storage life of the seed, it is better to sow it in the early monsoon, that is within three months of the date of collection. It should be sown in beds or trays under shade and treated like that of *Alnus nepalensis*. When the seedlings are about 5 cm tall they should be pricked out, either into polythene pots or, for raising stumps, into beds at a spacing of about 20 cm x 20 cm. Either method should produce plantable stock by the next monsoon.

Pests

The stem borer *Hypsipyla robusta* is a serious pest. No reports of damage by this insect have yet been recorded from Nepal, but as it occurs almost throughout the Old World tropics where trees of the family Meliaceae are found, it is unlikely that it will not occur here also. *Hypsipyla* is a moth, of which the larvae tunnel along the centre of young twigs, and under the bark of older trees. When the twigs are attacked the portion above the point of attack dies, and, if the tree survives, repeated dying back of the shoots eventually produces a very branchy misshapen tree of little value for timber. In addition to the shoot dieback, the presence of borer can be recognized by a gummy exudation near the point of attack. If the attack is recognized at an early stage some control is possible by cutting off the infested shoots and burning them, but recolonization by insects from the natural forest is always likely. The best way of avoiding attack is not to plant *T. ciliata* in large pure blocks in areas where *Hypsipyla* is present. If *T. ciliata* is planted in single lines in a plantation of other species, or under the shade of natural forest, attack is less likely.

Rate of growth

Under favourable site conditions, and where there is no stem borer attack, growth is rapid. No data are available from Nepal, but in Assam trees 22 years old had an average height of 19.2 m and an average diameter of 18 cm. Yield tables from Bengal give the following figures (Table 63, page 734) (Indian Timbers, 1969). Volume and biomass tables and equations are available in E.R. Sharma and Pukkala (1990a; 1990b).

Table 63—Growth of *Toona ciliata* from Bengal, India

Age (yr)	Height (m)	Diameter (cm)
5	11.3	11.9
10	16.5	18.3
15	20.1	23.1
20	22.6	26.7
25	24.1	30.1

Uses

Toona ciliata is a moderately hard, fairly light, easily worked and moderately durable timber. The heartwood is light brick red to reddish-brown. It is used for furniture, interior boards, planks, carvings, and cigar boxes. In parts of Nepal, however, its use inside houses is avoided for religious reasons. It weighs about 560 kg m^{-3} ; the calorific value of the sapwood is $21,700 \text{ kJ kg}^{-1}$, and that of the heartwood $21,400 \text{ kJ kg}^{-1}$. The leaves contain about 15 per cent crude protein, and are lopped for fodder when they are available. It is not, however, an important fodder tree in most areas. In Lalitpur District it was used to a small extent, in April, on southern slopes below 1250 m altitude (Upton, 1990).

Importance in Nepal

It has been planted on a fairly large scale in community plantations, and by private farmers, in some parts of Nepal (Mader and Stewart, 1983). In Pokhara there was 75 per cent survival in March from trees planted in the previous monsoon (Grob, 1982), but the overall rate of survival was considerably lower, 43 per cent in 1983/84 according to Ghimire and Nielsen (1985). It has a number of disadvantages. It only grows really well on moist fertile sites; the seed is rather difficult to collect; the largely superficial root system means that it should not be planted close to agricultural crops; and there are dangers of attack by shoot borer. For the time being only small-scale trials are recommended, especially of pure plantations.

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Gamble (1922); Ghosh (1977); Indian Timbers (1969); H.B. Joshi (1980); Lamichhane and Joshi (1980); Letourneux (1957); Mader and Stewart (1983); Magini and Tulstrup (1955); R.V. Singh (1982); Streets (1962); Trotter (1958); Troup (1921); Webb *et al.* (1984).

***Toona serrata* (Royle) M. Roem.**(Syn. *Cedrela serrata* Royle)

This species is found at higher altitudes than *T. ciliata*, between 2100 and 2300 m, mostly in western and central Nepal. Its timber is used for similar purposes to that of *T. ciliata*. The fodder is of medium to low quality. The tree produces numerous root suckers. Nursery techniques are similar to those for *T. ciliata*.

References: H.B. Joshi (1980); Troup (1921).

Toona microcarpa (C.DC) Harms (*Cedrela microcarpa*, C. DC) has been recorded from central Nepal, at an altitude of 1800 m. *Toona sureni* (Blume) Merrill (*Cedrela febrifuga* Blume) has been recorded from both west and east Nepal, at an altitude of 1200 m. Both are fast-growing trees producing useful timbers. See H.B. Joshi (1980).

***Trewia* L.**

Euphorbiaceae

***Trewia nudiflora* L.**

Nepali: gutel, gule kapasi, gamari, ramritha, pithar, ramphal.

Deciduous tree, branchlets woody. Leaves opposite, ovate, 11–20 cm by 7–12 cm, long pointed, hairy beneath when young, glabrous later; stalks 2–7.5 cm long. Male and female flowers on separate trees, males yellow in long lax drooping inflorescences, females green, solitary or 2–3 together in the leaf axils. Fruit fleshy, depressed globose, greyish-green, 3.5 cm by 3 cm. It has been recorded in Nepal from altitudes up to 1800 m, but is commonest below 1300 m. It is usually found in *Shorea robusta* forest especially in moist places near streams. It is a moderate light-demander, sensitive to drought, and fairly frost-hardy. It should only be planted on moist sites, or in moist areas where the soil has good reserves of water.

The fruit ripens in July–August, and each berry usually contains four seeds. There are about 50 fruits, and between 4000 and 8000 seeds kg⁻¹. The seed is extracted by drying the fruits in the sun and pressing out the seeds. Accounts of the viability of the seed vary; Troup (1921) reports that seed stored in tins had lost its viability within 12 months, but this is contradicted by M.W. Campbell (1983) who recommends storing the dried fruit in calico bags for eight months, then sowing the seed in beds in March and April under shade, and pricking out

the seedlings into polythene tubes. This will produce seedlings ready for planting in the monsoon. Growth appears to be fairly rapid. Four-year-old trees from seed, weeded but not watered, reached a maximum height of 5 m and a diameter of 5.7 cm. Tables and equations for biomass and volume are available in E.R. Sharma and Pukkala (1990a; 1990b).

The timber is soft and light (about 460 kg m⁻³) and is used for cheap planking and wood carving. It makes good match splints and in parts of the Terai is exported to India for this purpose. The leaves are lopped for fodder in India; they contain about 12.6 per cent crude protein.

References: M.W. Campbell (1983a); Gamble (1922); Lamichhaney and Joshi (1980); Magini and Tulstrup (1955); Troutter (1958); Troup (1921).

Trichilia P. Br.

Meliaceae

***Trichilia connaroides* (Wight & Arn.) Benth**

(Syn. *Heynea trijuga* Roxb. ex Sims, *Walsura trijuga* (Roxb.) Kurz)

Nepali: ankha tarua, komal siuli.

Tree up to 15 m tall. Leaves pinnate with 2–3 pairs of opposite leaflets and a terminal one, glabrous; leaflets 6–17 cm by 3.5–9 cm, apex acute or drawn out into a long point, margin without teeth. Inflorescences at the ends of long stout stalks, up to 30 cm long; flowers white or greenish, about 4 mm in diameter. Fruit red, ovoid, 1.5 cm by 1 cm, opening in two leathery valves when ripe; seed black with a thin white aril. It grows between 700 and 2400 m, and is found in some types of *Shorea robusta* forest, especially on the Siwaliks. It also extends into the *Schima-Castanopsis* forest and higher. It is found in the Kathmandu Valley. The seed ripens in November to January. There are about 4600 seeds kg⁻¹. Their viability is short, and they should be sown immediately after collection into polypots, with two seeds per pot, which are kept under shade at first. Seed sown when it is collected will produce plantable seedlings by the monsoon. The wood weighs about 860 kg m⁻³, and is used mostly for fuel. The bark and leaves have bitter and tonic properties, and are used medicinally. Bark, leaves and fruit are toxic. According to Gamble (1922) Nepalese use oil from the seeds for burning.

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Gamble (1922); Lamichhaney and Joshi (1980).

Tsuga Carr.

Pinaceae

Hemlock

Tsuga dumosa (D. Don) Eichler

(Syn. *T. brunoniana* (Wall.) Carriere)

Nepali: thingure salla, gobre salla. (Note: former name also used for *Abies* species, latter for *Pinus wallichiana*.)

Tree up to 40 m tall. Leaves 15–25 mm by 1.5–2 mm, unequal in size on same twig. Cones broadly ovoid 1.5–2.5 cm long. *Tsuga dumosa* is found in Nepal between 2100 and 3600 m. In the lower parts of its range it occurs in *Quercus semecarpifolia* forest, and higher up as a constituent of *Pinus wallichiana*, *Abies* and *Picea* forest. In some places, especially in the west, it forms almost pure stands. It grows on soils with a wide range of pH, from 4.3 to 7.5. The seed is collected between January and March, and is extracted by drying the cones in the sun. There are about 400,000 seeds kg⁻¹, and the viability is reported to be six months only. The seed should be sown in the spring once the weather has become warmer. It should be sown in beds or trays at the rate of about 250 g m⁻², and the seedlings pricked out into polypots when about 7 cm high. *Tsuga*, like *Pinus*, needs mycorrhizal soil in the potting mixture. At the altitudes where it is likely to be planted it may need two growing seasons in the nursery. At Ikudol, south Lalitpur District, 76 per cent of the trees planted by farmers survived, but at the higher altitudes of 3100 m at Kaku, Solukhumbu District, survival of seedlings planted in 1983 was very low, in part at least due to the use of bare-root seedlings for planting (J. Stewart, 1984). Growth is slow, the mean annual diameter increment ranging from about 0.3 to 0.45 cm. Mean annual increment in natural forest in the Darjeeling Hills in forest between 38–49 years old ranged from 8.4 to 10.9 m³ ha⁻¹. The timber is whitish and soft, and although not of the highest quality is used in villages at higher altitudes for house timber, doors and window frames. It is also used for shingles. It weighs about 450 kg m⁻³.

References: M.W. Campbell (1983a); Gamble (1922); Ghosh (1977); Lamichaney and Joshi (1980); Suri and Seth (1959); Streets (1962); Troup (1921).

Walsura trijuga see *Trichilia connaroides*.

Zizyphus Mill.

Rhamnaceae

Nepali: bayer.

Trees, shrubs or woody climbers. Branches usually thorny, with one straight and one curved thorn together. Leaves simple, alternate, three-nerved from the base. Flowers small, yellow or green, usually in short clusters in the leaf axils. Fruit a drupe.

Key to the species

- (1) Leaves downy above, ovate, 2.5–6 cm long; fruit 6 mm long, black; very large woody climber of Terai *Z. oenopia*
- (1) Leaves without hairs on upper side 2
- (2) Leaves with dense hairs on under side, sometimes losing them when old..... 3
- (2) Leaves without hairs on under side, except on the veins 5
- (3) Inflorescences large, of numerous flowers at the ends of leafless branches; thorns often single; leaves 5–15 cm long, ovate or elliptic, apex acute; fruit 6–8 mm long, yellowish *Z. rugosa*
- (3) Inflorescences shorter, of fewer flowers in the leaf axils 4
- (4) Fruit hard and woody, covered in grey hairs; thorns in pairs (occasionally none); leaves 3.5–9 cm long; Terai *Z. xylopyrus*
- (4) Fruit fleshy, yellow or red when ripe; thorns in pairs; leaves 1.8–6.3 cm long, dark green above, with dense pale hairs below; apex usually rounded; widespread *Z. mauritiana*
- (5) Young branches and inflorescences covered in silky rust-coloured hairs; leaves 6.5–10 cm long; no petals; shrub *Z. apetala*
- (5) Hairs not as above; petals present 6
- (6) Young shoots, leaf stalks, and veins on under side of leaves with straight adpressed hairs; leaves 5–10 cm by 2.5–4.3 cm, tapering to a point; fruit dark red when ripe; large shrub or small tree, widespread *Z. incurva*
- (6) Only a few scattered hairs on young parts; leaves 2.5–7.5 cm long, tapering to a point; fruit bright orange; small tree growing between 600 and 1800 m altitude *Z. oxyphylla*

***Zizyphus incurva* Roxb.**

Nepali: hade bayar.

This species occurs in central and eastern Nepal between 900 and 1600 m; it is common in the Kathmandu Valley. Its wood is used for similar purposes to that of *Z. mauritiana*, and its fruits are also edible. It is also a useful fodder species; it is used on a small scale in Lalitpur District. The fruit ripens between September and January. There are about 2700 dried stones kg⁻¹; germination is 40 per cent from fresh seeds. The seeds are sown in beds or trays in March, and the seedlings pricked out into containers when they are 3 cm tall, for planting out in the monsoon.

Reference: M.W. Campbell (1983a).

***Zizyphus mauritiana* Lam.**

(Syn. *Z. jujuba* (L.) Gaertn., not of Mill.)

Nepali: bayer.

This species is found in the Terai, the lower hills, and the duns, and near Pokhara, up to about 1200 m. It is often planted for its fruit, and for this improved cultivars may be used. It is a medium-sized deciduous tree, and a strong light-demander. It is resistant to frost and drought and recovers well after fire. It grows on a wide range of soils, and will tolerate moderately saline soils. Goats browse the young leaves. It coppices and pollards well, and produces root suckers. The fruit ripens between December and March; there are between 1000 and 2500 cleaned dry stones kg⁻¹ and each stone contains two seeds. The cleaned stones can be stored for up to five years in sealed containers, though during this period the viability drops from 95 to 30 per cent. Storage of the seed for four months to let it after-ripen improves germination (M.W. Campbell, 1983a); if facilities are available stratification in sand for 60–90 days at 5°C is recommended (Magini and Tulstrup, 1955). Scarification, extracting the seed from the stone, and treatment with sulphuric acid have also been recommended. In order to germinate, the seed needs full sunlight. It should be sown in trays or beds in March or April, and the seedlings pricked out when two pairs of true leaves have developed. The seedlings should also be given full light. It is likely that seedlings will need about 15 months in the nursery. Stumps may also be used. When propagating selected varieties for fruit, budding or ring-grafting is used. Growth is fairly fast; the mean annual diameter increment ranges from 0.8 to 1.3 cm.

The wood is hard, heavy and elastic, and is used for tool handles, agricultural implements, saddle trees, and the legs of bedsteads. It weighs about 930 kg m^{-3} , is a good fuel, and also makes excellent charcoal. The leaves are used for fodder, and contain 12.6–16.9 per cent crude protein. The total digestible nutrients are about 31 per cent. The fruit is edible and has a high content of vitamin C. Fruits of cultivated varieties vary considerably in size, shape and flavour. Fruit, leaves, root and bark are used medicinally. The tree is a good hedge plant.

References: M.W. Campbell (1983a); Forestry Research Institute (1963); Gamble (1922); H.B. Joshi (1980); Magini and Tulstrup (1958); National Academy of Sciences (1980); Panday (1982); Purseglove (1968); R.V. Singh (1982); Streets (1962); Troup (1921).

Zizyphus apetala Hook. f. ex Lawson. Recorded from 900 m in central Nepal. A shrub.

***Zizyphus oenoplia* (L.) Mill.**

Nepali: aule bayar.

A massive climber found in the Terai and foothills, so vigorous as to have become a pest in parts of India. The fruits are eaten fresh, and also dried for sale during the off-season. They are used to cure indigestion. The plant has been used as a live hedge.

References: H.B. Joshi (1980); Troup (1921).

Zizyphus oxyphylla Edgew. A small tree which has been recorded from western Nepal at 1400 m. Fruit edible.

***Zizyphus rugosa* Lam.**

Nepali: harray bayar.

A shrub, climber, or occasionally a small tree, associated with *Shorea robusta* forest, or riverain areas with *Acacia catechu*. The wood (720 kg m^{-3}) is used for fuel, and the leaves lopped for fodder.

***Zizyphus xylopyrus* (Retz.) Willd.**

Shrub or small tree from the Terai. The seed ripens in January to April; there are $210 \text{ seeds kg}^{-1}$. They should be depulped before they are sown. The wood has

similar uses to that of other *Zizyphus* species. The tree is an important host for the lac insect in parts of India.

References: H.B. Joshi (1980); Troup (1921).

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APPENDIX 1

Miscellaneous data

(1) Plants per hectare at different spacings

Spacing (m)	No. of plants	Spacing (feet)	No. of plants
1 x 1	10000	3 x 3	11960
1.5 x 1.5	4444	4 x 4	6728
2 x 2	2500	5 x 5	4306
2.5 x 2.5	1600	6 x 6	2990
3 x 3	1100	7 x 7	2197
4 x 4	625	8 x 8	1682
5 x 5	400	9 x 9	1329
6 x 6	278	10 x 10	1076
8 x 8	156	15 x 15	478
10 x 10	100	20 x 20	269
2 x 1	5000	30 x 30	120
2 x 3	1667	3 x 4	8970
2 x 4	1250	3 x 6	5980
2 x 5	1000	6 x 9	1993
3 x 4	833	6 x 12	1495
3 x 5	667	6 x 15	11963

(2) Nursery

- 1 filled polypot 3 inch x 7 inch (7.5 cm x 18 cm) lay-flat weighs 300 g and has a volume of about 300 ml of soil. The diameter of the filled pot = 5 cm (2 inch).
- 1 filled polypot 4 inch x 7 inch (10 cm x 18 cm) lay-flat weighs 530 g.
- 1 stand-out bed 10 m x 1 m can hold about 4300 seedlings in 3 inch x 7 inch lay-flat pots.
- 1 *doko* load of soil (25 kg) can fill about eighty 3 inch x 7 inch pots.

(3) Transport by *doko*

- Standard load 25 kg (30 kg in some localities).
- Daily walking distance 12 km.
- Volume of *doko* load of soil 0.6 cubic feet = 17 litres = approximately one kerosene tin.
- One *doko* can hold 80–100 seedlings in 3 inch x 7 inch lay-flat pots.

(4) Labour requirements (man-days)

Adapted from standard norms (Ministry of Forests and Soil Conservation, 1984).

(a) Nursery (per 10,000 plants)

Germination bed preparation	10
Seedling bed preparation	10
Sowing seed in bed	1
Sieving and mixing soil	10
Filling pots	40
Direct sowing into pots	5
Pricking out seedlings into pots	40
Weeding in beds and bags, —including insecticide spraying	4
Grading and shifting seedlings	2
Root pruning	2
Stump preparation	40

(b) Planting per hectare (2.5 m x 2.5 m = 1600 plants ha⁻¹)

Site clearance—open grassland	4
—25% covered with small bushes	10
—50% covered with small bushes	20
Pitting (30 cm x 30 cm x 30 cm pits)	
—soft loamy soil	19
—sandy soil	26
—sandy soil with gravel	32
gravel—hard soil with	38
Planting	25
Weeding—dense	20
—fairly dense	18
—fairly open	15

(5) Conversion factors

Imperial/US	Metric	Metric	Imperial/US
1 inch	= 2.54 cm	1 cm	= 0.3937 inch
1 yard	= 91.44 cm	1 m	= 1.094 yard
1 mile	= 1.609 km	1 km	= 0.6214 miles
1 sq. inch	= 6.452 cm ²	1 cm ²	= 0.1560 sq. inch
1 sq. ft	= 0.0929 m ²	1 m ²	= 10.76 sq. ft
1 sq. yd	= 0.8361 m ²	1 m ²	= 1.196 sq. yd
1 acre	= 0.4047 ha	1 ha	= 2.471 acres
1 sq. mile	= 2.590 km ²	1 km ²	= 0.3861 sq. mile
1 sq. ft/acre	= 0.2296 m ² ha ⁻¹	1 m ² ha ⁻¹	= 4.356 ft ² /acre
1 cu. ft	= 0.02832 m ³	1 m ³	= 35.32 cu. ft
1 cu. ft/acre	= 0.06998 m ³ ha ⁻¹	1 m ³ ha ⁻¹	= 14.29 cu.ft/acre
1 pint	= 0.5683 litre	1 litre	= 1.760 pint
1 gal (imperial)	= 4.546 litres	1 litre	= 0.220 gal (imperial)
1 gal (US)	= 3.785 litres	1 litre	= 0.2642 gal (US)
1 ounce (oz)	= 28.35 g	1 g	= 0.03527 oz
1 oz/sq. yd	= 33.91 g m ⁻²	1 g m ⁻²	= 0.02949 oz/sq. yd
1 pound (lb)	= 0.4536 kg	1 kg	= 2.205 lb
1 ton (2240 lb)	= 1.016 tonnes (t)	1 tonne	= 0.9842 tons

Nepali measures

1 <i>ropani</i>	= 0.052 ha (approx. 1/20 ha, or 1/8 acre)
1 <i>bigha</i>	= 0.68 ha (approx. 13 <i>ropani</i> , 2/3 ha, or 1.7 acres)
10 <i>muthi</i> (handfuls)	= 1 <i>mana</i> = about 0.56 litre
1 <i>pathi</i>	= 8 <i>mana</i> = about 4.5 litres = about 1 gallon
1 <i>muri</i>	= 20 <i>pathi</i> = about 90 litres
1 <i>maund</i>	= 36 kg approx.

(6) Nepalese Calendar

The lengths of Nepalese months vary between 29 and 32 days and are not constant from one year to the next. The following are their approximate equivalents in the western calendar

Baisakh	mid-April to mid-May
Jesth, Jeth	mid-May to mid-June
Asadh	mid-June to mid-July
Saaun, Srawan	mid-July to mid-August
Bhadra, Bhadau	mid-August to mid-September
Ashwin, Asauj	mid-September to mid-October
Kartik	mid-October to mid-November
Marga, Mangsir	mid-November to mid-December
Paush	mid-December to mid-January
Magha	mid-January to mid-February
Phalgun	mid-February to mid-March
Chaitra	mid-March to mid-April

The official era in Nepal is the Vikram Samvat, (V.S.) of which the new year begins on the first of Baisakh. The Vikram Samvat is 57 years ahead of the western calendar; thus the year beginning in mid-April 1994 A.D. is 2051 V.S.

APPENDIX 2

List of Nepali words used in text apart from names of trees

achar	A sort of pickle made from various fruits and vegetables, with spices and mustard oil.
alainchi	The large cardamom, <i>Amomum subulatum</i> .
amp	The mango, <i>Mangifera indica</i> .
Baisakh	The first month of the Nepali year, from mid-April to mid-May approximately.
ban mara	Introduced weedy shrubs, which during the last few decades have colonized large areas of Nepal. The lowland species is <i>Eupatorium odoratum</i> , and the highland species <i>E. adenophora</i> .
besar	Turmeric, <i>Curcuma domestica</i> , a spice used in curries, etc.
betel	The fruit of the palm, <i>Areca catechu</i> , chewed with 'pan'.
bhabar	The outwash zone at the base of the Siwalik Hills, often with very bouldery soils, in which many streams disappear underground.
bhitra madesh	The 'inner Terai' or duns, consisting of broad flat-bottomed valleys between the Siwalik Hills and the Mahabharat range, or between branches of the Siwalik Hills.
bigha	A measure of area used in the Terai, 0.68 ha.
Chaitra	The 12th month of the Nepali year, from mid-March to mid-April approximately.
chanda	<i>Hibiscus sabdariffa</i> , a herb with red calyces used in preparation of food and drinks.
chandra garuwa	<i>Rauwolfia serpentina</i> , a valuable medicinal plant the roots of which are the source of reserpine, used to treat high blood pressure.

chautara	A raised platform surrounded by a stone wall on which trees are usually planted, as a meeting place and a resting place for travellers.
chital	The spotted deer, <i>Axis axis</i> .
choya	A sort of string prepared from bamboos.
chuchche	A pointed pick-like implement, with a short handle, used as a hoe.
chutro	<i>Berberis</i> spp.
cutch	A tanning material extracted from the wood of <i>Acacia catechu</i> .
dasai, dasain	The most important festival in the Nepali Hindu year, occurring in the month of aswin (September–October).
dharni	A measure of weight, approximately 2.5 kg.
dhatela	The shrub, <i>Prinsepia utilis</i> .
dhungro	A cylindrical container made from a section of bamboo culm.
doko	A tapering basket made of bamboo and carried on the back—the usual way of transporting materials in the hills.
dun	A broad flat valley between the Siwalik Hills and the Mahabharat Range, or between branches of the Siwalik Hills.
gal	A crowbar.
ghangaru	<i>Pyracantha crenulata</i> , a spiny shrub used for hedging.
hathi kane	The prickly pear, <i>Opuntia</i> spp.
heralu	A forest watchman.
jalebi	<i>Pithecellobium dulce</i> , a shrub or small tree used for hedging.
jarayo	The sambhar deer, <i>Cervus unicolor</i> .
Jesth	The second month of the Nepali year, approximately mid-May to mid-June.
Kartik	The seventh month of the Nepali year, approximately mid-October to mid-November.
katha	A form of catechin, from <i>Acacia catechu</i> , used for chewing with betel and pan.

kettuke	<i>Agave</i> spp., (sisal), used for hedging, erosion control, and a source of fibre.
khet	Unirrigated crop land.
khukuri, khukri	A heavy knife carried by many Nepalese farmers and Gurkha soldiers.
khurpi	A sickle.
kodali	A hoe with a very broad blade and a short handle. Also used for a spade.
kodalo	A hoe with a smaller blade and longer handle than a kodali.
labra khada phul	<i>Euphorbia milii</i> , a small succulent spiny plant planted on the tops of walls to prevent goats climbing them.
madilo	<i>Eleagnus infundibuliformis</i> , a hedge plant.
Magh, Magha	The tenth month of the Nepali year, approximately mid-February to mid-March.
magel jhari	Light rains falling in winter.
mana	A Nepali measure of volume, about 0.56 litres.
Mangsir	The eighth month of the Nepali year, approximately mid-November to mid-December.
Marga	See Mangsir.
naike	A foreman, especially one in charge of a forest nursery.
namlo	The band over the head used to support a doko.
nanglo	A round tray made of bamboo.
pan	The leaf of <i>Piper betle</i> , chewed with betel nut.
panchayat	A group of villages administered by a council (<i>panch</i>).
pathi	A Nepali measure of volume, equivalent to eight <i>mana</i> or about 4.5 litres.
Paush	The ninth month of the Nepali year, approximately mid-December to mid-January.
Poush	See Paush.
rato mata	Deep red soil, very liable to erosion.
ropani	A measure of area in the hills of Nepal, about 1/20 hectare.
sambar	A large deer, <i>Cervus unicolor</i> .

sanai	<i>Crotalaria juncea</i> , a herbaceous plant used as a green manure and a source of fibre.
shakha	Secondary; of a nursery, a small supplementary nursery additional to the main nursery.
siru	<i>Imperata cylindrica</i> , a rhizomatous grass which is a serious weed in plantations.
Terai	Strictly, the area in the plains in which the water which soaks into the permeable soils of the Bhabar Terai zone reappears at the surface; more generally the plains of Nepal as distinct from the hills.
tihar	A five-day festival in the month of Kartik (October to November).
tite	Bitter, in taste.
tori	Mustard (<i>Brassica</i> sp.) cultivated for its oil.
Vikram Samvat	The official Nepali era, 57 years ahead of the European calendar. Abbreviated V.S.

APPENDIX 3

List of synonyms and minor species without separate headings

('=' indicates that the first name is a synonym or a name wrongly applied to the correct second name; 'see under' indicates a correctly named species which is mentioned in Volume 2 but does not have a separate heading.)

<i>Abies webbiana</i>	= <i>A. spectabilis</i>
<i>Acacia arabica</i>	= <i>A. nilotica</i>
<i>Acacia decurrens</i> var. <i>mollis</i>	= <i>A. mearnsii</i>
<i>Acacia mollissima</i>	= <i>A. mearnsii</i>
<i>Acacia omalophylla</i>	= <i>A. homalophylla</i>
<i>Adhatoda vasica</i>	= <i>Justicia adhatoda</i>
<i>Agati grandiflora</i>	= <i>Sesbania grandiflora</i>
<i>Albizia falcata</i>	= <i>A. falcataria</i>
<i>Albizia lucida</i>	= <i>A. lucidior</i>
<i>Albizia mollis</i>	= <i>A. julibrissin</i> var. <i>mollis</i>
<i>Albizia moluccana</i>	= <i>A. falcataria</i>
<i>Albizia stipulata</i>	= <i>A. chinensis</i>
<i>Allocasuarina littoralis</i>	= <i>Casuarina littoralis</i>
<i>Allocasuarina torulosa</i>	= <i>Casuarina torulosa</i>
<i>Alnus glutinosa</i>	see under <i>Alnus</i>
<i>Alnus hirsuta</i>	see under <i>Alnus</i>
<i>Alnus inokumae</i>	see under <i>Alnus</i>
<i>Alnus rubra</i>	see under <i>Alnus</i>
<i>Anthocephalus cadamba</i>	= <i>A. chinensis</i>
<i>Artocarpus integra</i>	= <i>A. integra</i>
<i>Artocarpus integrifolia</i>	= <i>A. integra</i>
<i>Bassia butyracea</i>	= <i>Aesandra butyracea</i>
<i>Bauhinia anguina</i>	= <i>B. scandens</i> var. <i>horsfieldii</i>
<i>Bauhinia longifolia</i>	= <i>B. purpurea</i>
<i>Bauhinia malabarica</i>	see under <i>Bauhinia</i>
<i>Bauhinia retusa</i>	= <i>B. semla</i>

<i>Bauhinia scandens</i> var. <i>horsfieldii</i>	see under <i>Bauhinia</i>
<i>Bauhinia semla</i>	see under <i>Bauhinia</i>
<i>Bauhinia vahlii</i>	see under <i>Bauhinia</i>
<i>Betula cylindrostachys</i>	= <i>B. alnoides</i>
<i>Betula jacquemontii</i>	= <i>B. utilis</i>
<i>Bombax malabaricum</i>	= <i>B. ceiba</i>
<i>Brassaiopsis aculeata</i>	see under <i>Brassaiopsis</i>
<i>Brassaiopsis mitis</i>	see under <i>Brassaiopsis</i>
<i>Brassaiopsis palmata</i>	= <i>B. polyacantha</i>
<i>Brassaiopsis polyacantha</i>	see under <i>Brassaiopsis</i>
<i>Brassaiopsis speciosa</i>	= <i>B. glomerulata</i>
<i>Bridelia pubescens</i>	see under <i>Bridelia</i>
<i>Bridelia stipularis</i>	see under <i>Bridelia</i>
<i>Bridelia tomentosa</i>	see under <i>Bridelia</i>
<i>Bucklandia populnea</i>	= <i>Exbucklandia populnea</i>
<i>Callistemon lanceolatus</i>	= <i>C. citrinus</i>
<i>Castanopsis lanceifolia</i>	see under <i>Castanopsis</i>
<i>Cedrela febrifuga</i>	= <i>Toona sureni</i>
<i>Cedrela microcarpa</i>	= <i>Toona microcarpa</i>
<i>Cedrela serrata</i>	= <i>Toona serrata</i>
<i>Cedrela toona</i>	= <i>Toona ciliata</i>
<i>Celtis cinnamomea</i>	= <i>C. timorensis</i>
<i>Celtis tetrandra</i>	see under <i>Celtis</i>
<i>Celtis timorensis</i>	see under <i>Celtis</i>
<i>Cinnamomum cecidodaphne</i>	= <i>C. glaucescens</i>
<i>Cordia alliodora</i>	see under <i>Cordia</i>
<i>Cordia grandis</i>	see under <i>Cordia</i>
<i>Cordia myxa</i>	= <i>C. dichotoma</i>
<i>Cupressus cashmeriana</i>	= <i>C. corneyana</i>
<i>Cupressus funebris</i>	= <i>C. corneyana</i>
<i>Dalbergia lanceolaria</i>	see under <i>Dalbergia</i>
<i>Dalbergia paniculata</i>	see under <i>Dalbergia</i>
<i>Dalbergia pinnata</i>	see under <i>Dalbergia</i>
<i>Dalbergia sericea</i>	see under <i>Dalbergia</i>
<i>Dalbergia stipulacea</i>	see under <i>Dalbergia</i>
<i>Daphne cannabina</i>	= <i>D. bholua</i> and <i>D. papyracea</i>
<i>Dendrocalamus</i> spp.	see under Bamboos
<i>Diospyros embryopteris</i>	= <i>D. malabarica</i>
<i>Diospyros kaki</i>	see under <i>Diospyros</i>
<i>Diospyros lancifolia</i>	see under <i>Diospyros</i>

<i>Diospyros lotus</i>	see under <i>Diospyros</i>
<i>Diospyros montana</i>	see under <i>Diospyros</i>
<i>Diospyros peregrina</i>	= <i>D. malabarica</i>
<i>Diospyros tomentosa</i>	see under <i>D. melanoxylon</i>
<i>Diospyros virginiana</i>	see under <i>Diospyros</i>
<i>Drepanostachyum</i> spp.	see under Bamboos
<i>Edgeworthia gardneri</i>	see under <i>Daphne</i>
<i>Elaeocarpus ganitrus</i>	= <i>E. sphaericus</i>
<i>Embllica officinalis</i>	= <i>Phyllanthus emblica</i>
<i>Eriodendron anfractuosum</i>	= <i>Ceiba pentandra</i>
<i>Eucalyptus bicostata</i>	= <i>E. globulus</i> subsp. <i>bicostata</i>
<i>Eucalyptus coolabah</i>	= <i>E. microtheca</i>
<i>Eucalyptus gigantea</i>	= <i>E. delegatensis</i>
<i>Eucalyptus goniocalyx</i>	= <i>E. cypellocarpa</i>
<i>Eucalyptus maculosa</i>	= <i>E. mannifera</i>
<i>Eucalyptus maidenii</i>	= <i>E. globulus</i> subsp. <i>maidenii</i>
<i>Eucalyptus</i> 'Mysore hybrid'	= <i>E. tereticornis</i>
<i>Eucalyptus rostrata</i>	= <i>E. camaldulensis</i>
<i>Eugenia jambolana</i>	= <i>Syzygium cumini</i>
<i>Eurya japonica</i>	= <i>E. acuminata</i>
<i>Eurya symplocina</i>	= <i>E. cerasifolia</i>
<i>Faidherbia albida</i>	= <i>Acacia albida</i>
<i>Ficus abelli</i>	see under <i>Ficus</i>
<i>Ficus altissima</i>	see under <i>Ficus</i>
<i>Ficus arnotiana</i>	see under <i>Ficus</i>
<i>Ficus benamina</i>	see under <i>Ficus</i>
<i>Ficus clavata</i>	= <i>F. subincisa</i>
<i>Ficus caria</i>	see under <i>Ficus</i>
<i>Ficus cunia</i>	= <i>F. semicordata</i>
<i>Ficus curtipes</i>	see under <i>Ficus</i>
<i>Ficus drupacea</i>	see under <i>Ficus</i>
<i>Ficus elastica</i>	see under <i>Ficus</i>
<i>Ficus geniculata</i>	see under <i>Ficus</i>
<i>Ficus hederacea</i>	see under <i>Ficus</i>
<i>Ficus heterophylla</i>	see under <i>Ficus</i>
<i>Ficus hirta</i>	see under <i>Ficus</i>
<i>Ficus hookeriana</i>	see under <i>Ficus</i>
<i>Ficus infectoria</i>	= <i>F. lacor</i>
<i>Ficus laevis</i>	see under <i>Ficus</i>
<i>Ficus microcarpa</i>	see under <i>Ficus</i>

<i>Ficus nemoralis</i>	= <i>F. neriifolia</i> var. <i>nemoralis</i>
<i>Ficus nervosa</i>	see under <i>Ficus</i>
<i>Ficus oligodon</i>	see under <i>Ficus</i>
<i>Ficus palamata</i>	see under <i>Ficus</i>
<i>Ficus pubigera</i>	see under <i>Ficus</i>
<i>Ficus pumilla</i>	see under <i>Ficus</i>
<i>Ficus roxburghii</i>	= <i>F. auriculata</i>
<i>Ficus rumphii</i>	see under <i>Ficus</i>
<i>Ficus sarmentosa</i>	see under <i>Ficus</i>
<i>Ficus squamosa</i>	see under <i>Ficus</i>
<i>Ficus subulata</i>	see under <i>Ficus</i>
<i>Ficus tinctoria</i>	see under <i>Ficus</i>
<i>Ficus virens</i>	= <i>F. lacor</i>
<i>Fraxinus micrantha</i>	see under <i>Fraxinus</i>
<i>Grewia asiatica</i>	= <i>G. subinaequalis</i> ; also see under <i>Grewia</i>
<i>Grewia asiatica</i> var. <i>vestita</i>	= <i>G. subinaequalis</i>
<i>Grewia disperma</i>	see under <i>Grewia</i>
<i>Grewia elastica</i>	see under <i>G. subinaequalis</i>
<i>Grewia helicterifolia</i>	see under <i>Grewia</i>
<i>Grewia laevigata</i>	= <i>G. disperma</i>
<i>Grewia oppositifolia</i>	= <i>G. optiva</i>
<i>Grewia polygama</i>	= <i>G. helicterifolia</i>
<i>Grewia tiliifolia</i>	see under <i>G. subinaequalis</i>
<i>Grewia vestita</i>	= <i>G. subinaequalis</i>
<i>Heynia trijuga</i>	= <i>Trichilia connaroides</i>
<i>Ilex doniana</i>	= <i>I. excelsa</i>
<i>Indigofera zollingeriana</i>	= <i>I. teysmannii</i>
<i>Jacaranda ovalifolia</i>	= <i>J. mimosifolia</i>
<i>Juniperus communis</i> var. <i>saxatilis</i>	see under <i>Juniperus</i>
<i>Juniperus macropoda</i>	= <i>J. recurva</i>
<i>Juniperus pseudosabina</i>	= <i>J. indica</i>
<i>Juniperus squamata</i>	see under <i>Juniperus</i>
<i>Juniperus wallichiana</i>	= <i>J. indica</i>
<i>Lagerstroemia flos-reginae</i>	= <i>L. reginae</i>
<i>Lagerstroemia indica</i>	see under <i>Lagerstroemia</i>
<i>Lagerstroemia reginae</i>	see under <i>Lagerstroemia</i>
<i>Lannea grandis</i>	= <i>L. coromandelica</i>
<i>Larix decidua</i>	see under <i>Larix</i>
<i>Larix griffithii</i>	= <i>L. griffithiana</i>

<i>Toona sureni</i>	see under <i>Toona</i>
<i>Tsuga brunoniana</i>	= <i>T. dumosa</i>
<i>Walsura trijuga</i>	= <i>Trichilia connaroides</i>
<i>Ziziphus apetala</i>	see under <i>Ziziphus</i>
<i>Ziziphus jujuba</i>	= <i>Z. mauritiana</i>
<i>Ziziphus oxyphylla</i>	see under <i>Ziziphus</i>

Nepali names of tree species included in text

abnush	<i>Diospyros melanoxylon</i>
adkaulo	<i>Lithocarpus elegans</i>
agar dhupi	<i>Cupressus torulosa</i>
agasthi, agasti	<i>Sesbania grandiflora</i>
agrath	<i>Shorea robusta</i>
alu bukhara	<i>Prunus domestica</i>
amala	<i>Phyllanthus emblica</i>
amaltas (amaltash)	<i>Cassia fistula</i>
amerika salla	<i>Pinus patula*</i>
amla, amlaka	<i>Phyllanthus emblica</i>
anjir	<i>Ficus auriculata</i>
ankha pakuwa	<i>Ficus subincisa</i>
ankha taruwa	<i>Trichilia connaroides</i>
arare	<i>Acacia pennata</i>
argali, argayle	<i>Daphne bholua, D. papyracea, D. sureil</i>
arjun	<i>Terminalia arjun</i>
arkaule, arkaulo, arkhola	<i>Lithocarpus elegans</i>
arphu	<i>Acacia pennata</i>
aru	<i>Prunus persica</i>
aru, jangali	<i>Prunus napaulensis</i>
aru pate	<i>Prunus cornuta, P. napaulensis</i>
aryili, aryuili	<i>Edgeworthia gardneri</i>
asare, ashare, ashare phul	<i>Lagerstroemia parviflora, L.spp.</i>
asna	<i>Terminalia alata</i>
assara, asuro	<i>Justicia adhatoda</i>
aulale salla	<i>Pinus roxburghii</i>
aule bayar	<i>Ziziphus oenoplia</i>
aule champ	<i>Michelia champaca</i>
aule chilaune	<i>Schima wallichii</i>
aule dabdabe	<i>Garuga pinnata</i>
aule kapase (kapasi)	<i>Trewia nudiflora</i>
aule salla	<i>Pinus roxburghii</i>
babul	<i>Acacia nilotica</i>
bada katus	<i>Lithocarpus pachyphylla</i>
badahar (badhar, bahar)	<i>Artocarpus lakoocha</i>
badam, kagati	<i>Prunus dulcis</i>
badam, kathiya	<i>Terminalia catappa</i>

bains, bainsh	<i>Salix</i> spp.
bajhi	<i>Anogeissus latifolia</i>
bajrant, bajrat	<i>Quercus lamellosa</i>
bakaino (bakainu, bakeno)	<i>Melia azedarach</i>
baluwa, kalo baluwa, seto baluwa	<i>Daphne bholua</i>
ban aru	<i>Prunus cornuta</i>
ban bans	<i>Dendrocalamus hamiltonii</i>
ban champ	<i>Michelia kisopa</i>
ban jamun	<i>Syzygium cumini</i>
ban paiyun	<i>Prunus cerasoides</i>
ban utis	<i>Betula alnoides</i>
banga	<i>Quercus lanata</i>
bange kath	<i>Populus ciliata</i>
bange salla	<i>Tsuga dumosa</i>
banghi (banjhi)	<i>Anogeissus latifolia</i>
bangikot	<i>Populus ciliata</i>
bangset, bangsher	<i>Quercus lamellosa</i>
banjh, banjho	<i>Quercus lanata, Q. leucotrichophora</i>
banjh katus	<i>Castanopsis indica</i>
banjh, sano	<i>Quercus leucotrichophora</i>
banjh, thulo	<i>Quercus lanata</i>
banmara	<i>Eupatorium adenophorum</i> (high altitudes)
banmara	<i>Eupatorium odoratum</i> (low altitudes)
bans	all large bamboos
bans, ban	<i>Dendrocalamus hamiltonii</i>
bans, bhalu	<i>Bambusa balcooa, Dendrocalamus giganteus, D. hookeri</i>
bans, choya	<i>Dendrocalamus hamiltonii</i>
bans, dhanu	<i>Bambusa balcooa</i>
bans, dhungre	<i>Dendrocalamus</i> sp. (D6)
bans, gopi	<i>Cephalostachyum capitatum, Dendrocalamus patellaris</i>
bans, haruti	<i>Bambusa balcooa</i>
bans, kalo	<i>Dendrocalamus hookeri</i>
bans, kalo tama	<i>Dendrocalamus hookeri</i>
bans, kante	<i>Bambusa arundinacea</i>
bans, kata	<i>Phyllostachys</i> sp.
bans, kath	<i>Dendrocalamus strictus</i>
bans, khosre	<i>Dendrocalamus</i> sp. (D13)
bans, koirancho	<i>Oxytenanthera</i> or <i>Bambusa</i> sp.

bans, lathi	<i>Dendrocalamus strictus</i>
bans, lyas	<i>Dendrocalamus patellaris</i>
bans, mal	<i>Bambusa nutans</i>
bans, mokla	<i>Bambusa</i> sp.
bans, murali	<i>Dendrocalamus patellaris</i>
bans, nibha	<i>Dendrocalamus patellaris</i>
bans, pahelo	<i>Bambusa glaucescens</i> var. <i>striatus</i>
bans, phusre	<i>Dendrocalamus</i> sp. (D13)
bans, sate	<i>Bambusa</i> sp. (B21)
bans, tama	<i>Dendrocalamus hamiltonii</i> , <i>D.</i> sp. (D13)
bans, tharu	<i>Bambusa</i> sp. (B21), <i>B. tulda</i>
bansi	<i>Quercus lamellosa</i>
bar	<i>Ficus benghalensis</i>
bara	<i>Lannea coromandelica</i>
bara katus	<i>Castanopsis hystrix</i>
barma salla, barme salla	<i>Taxus baccata</i>
barro, barhu	<i>Terminalia bellirica</i>
baruwa	<i>Daphne bholua</i> , <i>D. papyracea</i>
bayar, bayer	<i>Ziziphus</i> spp.
bayer, aule	<i>Ziziphus oenoplia</i>
bayer, hade	<i>Ziziphus incurva</i>
bayer, harray	<i>Ziziphus rugosa</i>
belekharmando, -mendo	<i>Quercus floribunda</i>
ber	<i>Ziziphus</i> spp.
berulo	<i>Ficus subincisa</i>
bhalu bans	<i>Bambusa balcooa</i> , <i>Dendrocalamus giganteus</i> , <i>D. hookeri</i>
bhashak, kalo	<i>Justicia adhatoda</i>
bhewul	<i>Grewia optiva</i>
bhimal	<i>Grewia optiva</i>
bhimsenpate	<i>Buddleja asiatica</i>
bhiyal	<i>Grewia optiva</i>
bhoddaire	<i>Lagerstroemia parviflora</i>
bhojpatra, bhujpatra	<i>Betula utilis</i>
bhokra, bhokre	<i>Ilex excelsa</i>
bhorans	<i>Rhododendron arboreum</i>
bhorla	<i>Bauhinia vahlii</i>
bogre salla	<i>Larix griffithianus</i>
bohandi	<i>Grewia optiva</i>
bohar	<i>Ficus benghalensis</i>

bohorì	<i>Cordia dichotoma</i>
borran	<i>Artocarpus lakoocha</i>
bot adheyaro, bot dhayero	<i>Lagerstroemia parviflora</i>
buddhi dhaiyare	<i>Lagerstroemia parviflora</i>
bunge salla	<i>Abies spectabilis</i>
burma salla	<i>Taxus baccata</i>
chakhoonda, chakhoonda swan	<i>Jacaranda mimosifolia</i>
champ	<i>Michelia champaca</i> , <i>M. doltropa</i>
champ, aule	<i>Michelia champaca</i>
champ, ban	<i>Michelia kisopa</i>
champ, gogai	<i>Michelia velutina</i>
champ, phul	<i>Michelia champaca</i>
champ, phusre	<i>Michelia velutina</i>
champ, pulni*	<i>Michelia doltropa</i>
champ, rani	<i>Michelia doltropa</i>
champ, seto	<i>Michelia doltropa</i> , <i>M. kisopa</i>
champ, suna	<i>Michelia champaca</i>
chandar	<i>Daphniphyllum himalense</i>
chigar	<i>Thamnocalamus</i> sp.
chilaune, aule chilaune	<i>Schima wallichii</i>
chilro	<i>Abies densa</i>
chingure	<i>Abies pindrow</i>
chiuri	<i>Aesandra butyracea</i>
choya bans	<i>Dendrocalamus hamiltonii</i>
chuletro, seto chuletro	<i>Brassaiopsis hainla</i>
chuletro, kalo	<i>Brassaiopsis glomerulata</i>
dabadabi, dabdabe	<i>Lannea coromandelica</i>
dabdabe, aule dabdabe	<i>Garuga pinnata</i>
dabre	<i>Quercus lamellosa</i>
dalchini	<i>Cinnamomum tamala</i>
dangdinge	<i>Brassaiopsis polyacantha</i>
dante okhar	<i>Juglans regia</i>
dar	<i>Boehmeria rugulosa</i>
daura	<i>Anogeissus latifolia</i>
deshi katus	<i>Castanea sativa</i>
devdara, dewar	<i>Cedrus deodara</i>
dhale katus	<i>Castanopsis indica</i>
dhaman	<i>Grewia optiva</i>
dhanu bans	<i>Bambusa balcooa</i>
dhengre salla	<i>Taxus baccata</i> subsp. <i>wallichiana</i>

dhungre bans	<i>Dendrocalamus</i> sp. (D6)
dhupi	<i>Cupressus</i> spp., <i>Juniperus</i> spp.
dhupi, agar	<i>Cupressus torulosa</i>
dhupi salla	<i>Cryptomeria japonica</i>
dudhilo	<i>Ficus neriifolia</i> var. <i>nemoralis</i>
dumri	<i>Ficus glomerata</i>
dun siris	<i>Albizia procera</i>
gamari	<i>Gmelina arborea</i> , <i>Trewia nudiflora</i>
gayo	<i>Bridelia retusa</i>
gedilo	<i>Ficus subincisa</i>
ghatle	<i>Grewia optiva</i>
ghesi	<i>Quercus semecarpifolia</i>
ghorans	<i>Rhododendron arboreum</i>
ghore	<i>Thamnocalamus</i> sp.
ghurmiso	<i>Leucoscepttrum canum</i>
githi	<i>Boehmeria rugulosa</i>
gobre salla	<i>Abies densa</i> , <i>A. pindrow</i> , <i>A. spectabilis</i> , <i>Pinus wallichiana</i> , <i>Tsuga dumosa</i>
gogai champ	<i>Michelia velutina</i>
gogan, aule gogan	<i>Saurauia napaulensis</i>
gogane	<i>Quercus lamellosa</i>
gole simta	<i>Pinus gerardiana</i>
gopi bans	<i>Cephalostachyum capitatum</i> , or <i>Dendrocalamus patellaris</i>
gulab jamun	<i>Syzygium jambos</i>
gular	<i>Ficus glomerata</i>
gule kapasi	<i>Trewia nudiflora</i>
gurans	<i>Rhododendron arboreum</i>
gutel	<i>Trewia nudiflora</i>
hade bayer	<i>Ziziphus incurva</i>
hade okhar	<i>Juglans regia</i> var. <i>kamaonia</i>
halabed	<i>Diospyros lotus</i> , <i>D. virginiana</i> , <i>D. malabarica</i>
haldu	<i>Adina cordifolia</i>
hallongre	<i>Lannea coromandelica</i>
hareto	<i>Ficus auriculata</i>
harray bayer	<i>Ziziphus rugosa</i>
harro, jangali harro, thulo harro	<i>Terminalia chebula</i>
haruti bans	<i>Bambusa balcooa</i>

lyas bans	<i>Dendrocalamus patellaris</i>
mago (Tamang)	<i>Ficus neriifolia</i> var. <i>nemorosa</i>
maharukh	<i>Ailanthus excelsa</i>
mal bans	<i>Bambusa nutans</i>
malayagiri	<i>Cinnamomum glaucescens</i>
malinge nigalo	<i>Drepanostachyum</i> spp.
malingo	<i>Arundinaria maling</i>
mashala	<i>Eucalyptus</i> spp. (all)
mayal, mayel, mel	<i>Pyrus pashia</i>
mokla bans	<i>Bambusa</i> sp.
mulu	<i>Bauhinia vahlii</i>
murali bans	<i>Dendrocalamus patellaris</i>
musure katus	<i>Castanopsis tribuloides</i>
naspati	<i>Pyrus communis</i>
naru	<i>Aesculus indica</i>
nebharo	<i>Ficus auriculata</i>
nibha bans	<i>Dendrocalamus patellaris</i>
nigalo, kalo	<i>Phyllostachys nigra</i>
nigalo, malingo	<i>Drepanostachyum</i> spp.
nigalo, tite	<i>Drepanostachyum intermedium</i> , <i>D. khasianum</i>
nim	<i>Azadirachta indica</i>
nimmaro	<i>Ficus auriculata</i>
ningalo	see nigalo
okhar	<i>Juglans regia</i>
padang	<i>Drepanostachyum hookerianum</i>
pahelo bans	<i>Bambusa glaucescens</i> var. <i>striatus</i>
paingyo, painyo, painyu	<i>Prunus cerasoides</i>
paiyu	<i>Betula alnoides</i>
paiyun, ban paiyun	<i>Prunus cerasoides</i>
pajan (Sherpa)	<i>Eurya acuminata</i>
pakhure	<i>Ficus glaberrima</i>
pangar, pangre	<i>Aesculus indica</i>
pani saj	<i>Terminalia myriocarpa</i>
patar	<i>Ficus rumphii</i>
patle katus	<i>Castanopsis hystrix</i>
patle salla, patula salla	<i>Pinus patula</i>
patmaro	<i>Litsea monopetala</i>
phalant	<i>Quercus glauca</i> , <i>Q. lamellosa</i> , <i>Q. oxyodon</i>

phalant, sano	<i>Quercus glauca</i> , <i>Q. lanata</i>
phalant, sano pate	<i>Quercus glauca</i>
phalant, thulo	<i>Quercus lamellosa</i>
phaledo	<i>Erythrina</i> (all species)
phalsa	<i>Grewia subinaequalis</i> , <i>G. asiatica</i>
phangus	<i>Aesculus indica</i>
phanir	<i>Syzygium cumini</i>
pharat, singhali	<i>Quercus lamellosa</i>
phasre	<i>Grewia subinaequalis</i>
phirphire	<i>Acer oblongum</i>
phitar	<i>Trewia nudiflora</i>
phosra	<i>Grewia subinaequalis</i>
phul champ	<i>Michelia champaca</i>
phusre, phusro	<i>Grewia subinaequalis</i>
phusre bans	<i>Dendrocalamus</i> sp. (D.13)
phusre champ	<i>Michelia velutina</i>
pinge	<i>Cinnamomum tamala</i>
pipal	<i>Ficus religiosa</i>
pipla	<i>Exbucklandia populnea</i>
pithar	<i>Trewia nudiflora</i>
putali phul	<i>Acer oblongum</i>
putnero	<i>Litsea monopetala</i>
puwale, puwanle	<i>Ilex excelsa</i>
ragdatenden	<i>Daphniphyllum himalense</i>
rajbriksha	<i>Cassia fistula</i>
raj salla	<i>Cupressus torulosa</i>
rakchan	<i>Daphniphyllum himalense</i>
ramphal	<i>Trewia nudiflora</i>
ramritha	<i>Trewia nudiflora</i>
rani champ	<i>Michelia doltsopa</i>
rani salla	<i>Pinus roxburghii</i>
ratmati	<i>Litsea monopetala</i>
rato koiralo	<i>Bauhinia purpurea</i>
rato siris	<i>Albizia chinensis</i> , <i>A. julibrissin</i> var. <i>mollis</i>
ringal	<i>Thamnocalamus spathiflorus</i>
ris	<i>Litsea monopetala</i>
ritha	<i>Sapindus mukorossi</i>
rudrakshiya	<i>Elaeocarpus sphaericus</i>
sabban, sagawan	<i>Tectona grandis</i>
sahijan	<i>Moringa oleifera</i>

saj
 saj, pani
 sakhuwan
 sal
 salla
 salla, amerika
 salla, aulale
 salla, aule
 salla, barme
 salla, bogre
 salla, bunge
 salla, burma
 salla, dhengre
 salla, dhupi
 salla, gobre

 salla, khote
 salla, lekali
 salla, patle, patula
 salla, raj
 salla, rani
 salla, thingure
 sano banjh
 sano jhyanu
 sano pate phalant
 sano phalant
 sate bans
 satisal
 saur
 seto baluwa
 seto champ
 seto chuletro
 seto koiralo
 seto siris
 shalsi
 shobanjan
 siltimur
 simal
 sinajya swan (Newari)

Terminalia alata
Terminalia myriocarpa
Shorea robusta
Shorea robusta
Pinus spp. and other conifers
Pinus patula
Pinus roxburghii
Pinus roxburghii
Taxus baccata subsp. *wallichiana*
Larix griffithianus
Abies spectabilis
Taxus baccata subsp. *wallichiana*
Taxus baccata subsp. *wallichiana*
Cryptomeria japonica
Pinus wallichiana, *Abies densa*,
A. pindrow, *A. spectabilis*,
Tsuga dumosa
Pinus roxburghii
Pinus wallichiana
Pinus patula
Cupressus torulosa
Pinus roxburghii
Tsuga dumosa
Quercus leucotrichophora
Eurya acuminata
Quercus glauca, *Q. lanata*
Quercus glauca, *Q. lanata*
Bambusa sp. (B21)
Dalbergia latifolia
Betula alnoides
Daphne spp.
Michelia kisopa
Brassaiopsis hainla
Bauhinia variegata
Albizia procera
Quercus lamellosa
Moringa oleifera
Litsea cubeba
Bombax ceiba
Lagerstroemia indica

siran, sirin	<i>Albizia chinensis</i>
siris	<i>Albizia</i> spp.
siris, dun	<i>Albizia procera</i>
siris, kalo	<i>Albizia chinensis</i> , <i>A. lebbeck</i>
siris, rato	<i>Albizia chinensis</i> , <i>A. julibrissin</i> var. <i>mollis</i>
siris, seto	<i>Albizia procera</i>
sisau	<i>Dalbergia sissoo</i>
suganda kokila	<i>Cinnamomum glaucescens</i>
sunā champ	<i>Michelia velutina</i>
syal phusre, phusro	<i>Grewia optiva</i> , <i>G. subinaequalis</i>
talis patra	<i>Abies spectabilis</i> , <i>Larix griffithiana</i>
tama bans	<i>Dendrocalamus hamiltonii</i> , <i>D. sp.</i> (D13)
tanki	<i>Bauhinia purpurea</i>
tanki, amili	<i>Bauhinia malabarica</i>
tati bare	<i>Dalbergia stipulacea</i>
tejpat	<i>Cinnamomum tamala</i>
teju	<i>Diospyros malabarica</i>
tendu	<i>Diospyros malabarica</i> , <i>D. melanoxylon</i>
tengar (Tamang)	<i>Eurya acuminata</i>
tharu bans	<i>Bambusa</i> sp. (B21), <i>B. tulda</i>
thingure salla	<i>Tsuga dumosa</i> , <i>Abies</i> sp.
thinke	<i>Quercus floribunda</i>
thotne	<i>Ficus hispida</i>
thulo banjh	<i>Quercus lanata</i>
thulo harro	<i>Terminalia chebula</i>
thulo phalant	<i>Quercus lamellosa</i>
thyasu	<i>Eurya acuminata</i>
timilo	<i>Ficus auriculata</i>
tingar, tingare	<i>Eurya acuminata</i>
tite nigalo	<i>Drepanostachyum intermedium</i> , <i>D. khasianum</i>
tote	<i>Ficus hispida</i>
tuna, tuni	<i>Toona ciliata</i>
utis	<i>Alnus nepalensis</i>
utis, ban	<i>Betula alnoides</i>
yali, yarla	<i>Acer campbellii</i>

English and trade names

acacia, false	<i>Robinia pseudoacacia</i>
alder	<i>Alnus</i> spp.
almond	<i>Prunus dulcis</i>
almond, Indian	<i>Terminalia catappa</i>
apricot	<i>Prunus armeniaca</i>
ash	<i>Fraxinus</i> spp.
Australian blackwood	<i>Acacia melanoxylon</i>
birch	<i>Betula</i> spp.
black wattle	<i>Acacia mearnsii</i>
blackwood, Australian	<i>Acacia melanoxylon</i>
blue pine	<i>Pinus wallichiana</i>
bottle brush tree	<i>Callistemon citrinus</i>
camphor	<i>Cinnamomum camphora</i>
carob	<i>Ceratonia siliqua</i>
cedar	<i>Cedrus</i> spp.
champedak	<i>Artocarpus integra</i>
cherry	<i>Prunus avium</i>
cherry plum	<i>Prunus cerasifera</i>
chestnut	<i>Castanea sativa</i>
chestnut (loosely)	<i>Castanopsis</i> spp.
Chilghoza pine	<i>Pinus gerrardiana</i>
chir pine	<i>Pinus roxburghii</i>
coolibah (Austr.)	<i>Eucalyptus microtheca</i>
cottonwood, eastern	<i>Populus deltoides</i>
cypress	<i>Cupressus</i> spp.
deodar	<i>Cedrus deodara</i>
fig	<i>Ficus</i> spp.
fir, silver	<i>Abies</i> spp.
green wattle	<i>Acacia decurrens</i>
haldu	<i>Adina cordifolia</i>
hemlock	<i>Tsuga</i> spp.
honey locust	<i>Gleditsia triacanthos</i>
horse chestnut	<i>Aesculus indica</i>
Indian almond	<i>Terminalia catappa</i>
Indian laurel	<i>Terminalia alata</i>
Indian rosewood	<i>Dalbergia latifolia</i>
jack fruit	<i>Artocarpus heterophyllus</i>

juniper	<i>Juniperus</i> spp.
kapok	<i>Ceiba pentandra</i>
kokko	<i>Albizia lebbek</i>
larch	<i>Larix</i> spp.
laurel, Indian	<i>Terminalia alata</i>
locust, black	<i>Robinia pseudoacacia</i>
locust, honey	<i>Gleditsia triacanthos</i>
mangium (Austr.)	<i>Acacia mangium</i>
maple	<i>Acer</i> spp.
mulberry	<i>Morus</i> spp.
mulberry, paper	<i>Broussonetia papyrifera</i>
neem	<i>Azadirachta indica</i>
oak	<i>Quercus</i> and <i>Lithocarpus</i> spp.
oak, silky	<i>Grevillea robusta</i>
paper mulberry	<i>Broussonetia papyrifera</i>
peach	
peepul	<i>Ficus religiosa</i>
persimmon	<i>Diospyros</i> spp.
Persian lilac	<i>Melia azedarach</i>
pine	<i>Pinus</i> spp.
pine, blue	<i>Pinus wallichiana</i>
pine, Chilghoza	<i>Pinus gerardiana</i>
pine, chir	<i>Pinus roxburghii</i>
pine, loblolly	<i>Pinus taeda</i>
pine, slash	<i>Pinus elliotii</i>
plum	<i>Prunus domestica</i>
plum, cherry	<i>Prunus cerasifera</i>
poplar	<i>Populus</i> spp.
poplar, Lombardy	<i>Populus nigra</i> cv. 'italica'
poplar, white	<i>Populus alba</i>
red silk-cotton	<i>Bombax ceiba</i>
rose apple	<i>Syzygium jambos</i>
rosewood, Indian	<i>Dalbergia latifolia</i>
sal	<i>Shorea robusta</i>
silk-cotton, red	<i>Bombax ceiba</i>
silky oak	<i>Grevillea robusta</i>
silver fir	<i>Abies</i> spp.
silver wattle	<i>Acacia dealbata</i>
sissoo	<i>Dalbergia sissoo</i>
teak	<i>Tectona grandis</i>

Appendices

toon	<i>Toona ciliata</i>
walnut	<i>Juglans regia</i>
wattle, black	<i>Acacia mearnsii</i>
wattle, green	<i>Acacia decurrens</i>
wattle, silver	<i>Acacia dealbata</i>
willow	<i>Salix</i> spp.
willow, weeping	<i>Salix babylonica</i>
yew	<i>Taxus baccata</i> subsp. <i>wallichiana</i>