MAPPING OF LARGE AND COMPLEX LANDSLIDES

The *Roadside Bio-engineering, Site Handbook* gives a simple procedure and proforma for site assessment, as a guide to assessing the treatment needs of bare and unstable slopes. That is adequate for the majority of cases. However, in the case of large and complex landslides, a more detailed procedure for site assessment is required. This is necessary to ensure that all aspects of the failure are addressed. It can then be used either as a basis for determining the remedial treatment or in discussing the need for a full investigation by specialists. However, an experienced and conscientious professional will be able to assess almost every aspect of a landslide from the procedure described here.

This procedure will help you to map an unstable site and observe all its significant features. The procedure is given in logical order but you do not have to follow this order in every case. An advantage of observing the site in a methodical way is that there will be less risk of missing an important feature. The column on the right suggests the action you should take.

The basis of the site record is a drawing of the site. A simple sketch will do. It does not have to be to scale. Its purpose is to help you to understand the geometric relationships between features of the landslide. It also enables you to record concisely your measurements and where you took them from. Any notes you make can also go on the drawing, but if they are lengthy, or if you wish to describe some detail of the slide by additional drawings and notes, these are best recorded separately in your notebook. It is good practice to make all your drawings and notes in one notebook. In this way pages do not get lost and records are kept in sequence.

The equipment you will need is as follows:

- clipboard, pen and paper;
- a copy of Annex A of the *Roadside Bio-engineering, Reference Manual*; optionally, you can take the whole *Reference Manual* to refer to on site;
- a copy of the *Roadside Bio-engineering, Site Handbook*;
- a hammer;
- a compass-clinometer (available from the Geo-Environmental Unit of the Department of Roads); alternatively, a simple compass and an Abney level;
- (optionally) 30-metre and 3-metre tape measures;
- (optionally) a geological hand lens for close inspection of rock conditions (available from the Geo-Environmental Unit of the Department of Roads).

Procedure for the mapping of large and complex landslides

Procedural steps		Action
Stage 1	**Initial observations of the geomorphology.** Look at the general locality and situation of the site: • make a note of the exact location so that you can direct others to the site if necessary; • see if it is in a part of the landscape where instability would be expected (refer to Figures 2.6 and 2.7 in the *Reference Manual* pages 51,52); • see if the orientation of the rocks, outcropping on the hillside around the site, indicate that the cause of the failure may be due to rock structure, either as planes of weakness or movement of water along fractures; • look at other sites in the area: they may have a similar geomorphic situation and a similar life progression.	**Observe**
Stage 2	**Sketch the site from the road or other good observation point**	**Draw**
(a)	Draw the main features: • concentrate on getting the general proportions correct; • estimate the length from top to bottom: record this on the drawing; • estimate the width across the base: record this; • sometimes the landslide may be very complex, and some additional sub-drawings may help.	
(b)	Look for the landslide zones: • scar; • transport; • debris. Note that you cannot yet see whether there is a zone of cracking above the scar. You do not have to record these zones on the drawing, but the completed drawing should be sufficiently well illustrated and labelled to let another person recognise which zones are present and where they are.	**Draw**
(c)	Examine the material forming the original hill slope: • debris; • soft rock; • hard rock; • alternating hard and soft rocks. All of these could be present on one landslide. The drawing should show where they are. You will have to check your classes during the site walkover (Stage 3b).	**Describe and draw**
(d)	Sketch a slope profile of the site from top to bottom. Angles do not have to be precise, but should indicate relative steepness. It can be augmented with more detail (*e.g.* with slope measurements) as you walk up the slide. Note that slopes >35° tend to be unstable unless composed of solid rock.	**Draw**
(e)	Sketch the surface water drainage: • streams; • any springs that may be visible from where you are standing.	**Draw**
(f)	Sketch areas of rock outcrop.	**Draw**
(g)	Landmarks: note any obvious landmarks on the site, such as prominent trees. This will help you to keep your bearings as you walk over and around the site.	**Draw**

Procedure for the mapping of large and complex landslides *continued*

Procedural steps		Action
Stage 3	**Walkover survey**	
(a)	Walk up the centre of the slide to the crown (head of scar). Measure the angles of major slope units. If the slope is too steep or dangerous, walk around the edge, looking into the scar.	**Measure**
(b)	Rock: visit each rock outcrop. Measure any relevant rock planes (see Chapter 2.4c of the *Reference Manual*, page 54, or observe how the planes relate to the slope and failure planes. Make sure that the rocks observed are true outcrops (attached to solid rock beneath) and not simply large boulders partly buried on the slope. Check the weathering grade: hard rock is from weathering grades 1 to 4 and rings when struck with a hammer); soft rock is in weathering grade 5 or softer, and gives a dull thud when struck with a hammer). Note the: • uniformity or layering (bedding) of the rock units; • degree of weathering (hardness and discoloration of minerals) of the rocks; • degree of fracturing, especially any open fractures; • signs of water movement along fractures.	**and describe**
(c)	Debris and slope: indicate the area of the slide that is occupied by debris: • location and extent of landslide debris; • composition of debris; • wetness of debris; • depth of debris / depth of failure plane; • location, orientation and size of any cracks in the debris or on the slope; • any back-tilted slope, where water may collect (if this is present, it indicates a deep-seated circular failure – a shear failure); • tilted trees: these can indicate subsiding ground; • disrupted engineering structures, *e.g.* masonry surface drains; • points of ground water seepage.	**Describe and draw**
(d)	Margins and top. Look for the following. • Cracks in the ground: cracks are most frequent above the head of a slide, but they often occur also around the sides. The presence of cracks shows that the ground is under tension and that it will probably fail, and soon. Note the location, dimensions and orientation of the cracks. This information tells you where, and in which direction, the ground is under tension. The area of cracking tells you the area over which failure is about to take place; • Streams, springs, irrigation channels or drainage structures, especially masonry drainage ditches. These features may be sending water into the slide. They may either have caused it in the first place, or they may be contributing to further failure. Irrigation channels and masonry drainage ditches should be inspected closely for any signs of cracking and leakage; • Irregular topography, not due to rock outcrops. This may indicate the presence of an old landslide, in which case you will have to survey the whole of this, too. Continue walking up the slope above the landslide until there is no further evidence of instability. This may mean walking at least 50 metres higher than the landslide scar, and much further if necessary.	**Draw**
(e)	Base of the slide: describe the features and ground conditions at the base. Possibilities are as follows. • Intact road. Instability is from above only. The road may be buried but the road itself is not disrupted by the slide plane. Note: if the road is disturbed, the road cannot be at the base and the slope condition at the base must come under one of the three categories below. • Stable, undisturbed hill slope. • Unstable hill slope. Cracked ground, landslide or topography that collects water. • Stream, with a possible risk of scour and undercutting of slope.	**Describe**

Procedure for the mapping of large and complex landslides *continued*

Procedural steps		Action
Stage 4	**General assessment**	**Describe**
(a)	Causes and mechanisms of instability. Based on your observations, assess whether any part of the failure is due to the following causes. Mark them on your plan of the site. Surface water • Erosion, or soaking of surface to cause shallow sliding. • Effects of water infiltrating from surface. Causes shallow failures. Ground water • Ground water causes increased pore water pressure at depth. • Failure plane is deeper than in surface water failure. Weathering • Rock shear strength is reduced by weathering. Rock strength is reduced as constituent minerals are broken down into weathering products and clay minerals. Physical bonds between rock constituents are weakened or broken. The rock can fail along weakened fracture planes or through its body. Undercutting • Slope is undercut by a flowing stream or by the opening up of a road cutting. • Incision (downcutting) or lateral scour by streams is a major cause of slope failure. The initial failure can work rapidly up slope. Addition of weight • Weight added usually by landslide debris from above or by the dumping of spoil.	
(b)	History and life progression of slide. Assess the likely evolution of the slide from its current condition into the future. Possibilities are as follows. • Stable slope formed, or will stabilise naturally • Single failure to stable rock plane or stable slope configuration. This is a relatively rare situation. • Further movement is expected, by a less serious mechanism. 'Less serious mechanism' means a movement at a depth shallower than that of the original failure. This means that the instability is going through post-slide adjustment. • Repeated movement expected, by the initial mechanism or another equally serious. • Further movement is expected, by a more serious mechanism. 'More serious mechanism' means a movement at a greater depth than that involved in the original failure, or a mass movement involving a different cause or mechanism.	**Describe**
(c)	Severity of instability Fill in the *Check List for Assessing Severity of Slope Instability*. (*Reference Manual*, Annex A). This does not quantify the severity (it is still impossible to do so in a way which permits meaningful comparisons) but allows you to assess the severity rapidly. On the check list, the criteria in each category get progressively larger, more difficult and harder to rectify. Therefore in assessing severity, you should look at how far down each list you have ticked each of the twelve categories.	**Check list**
Stage 5	**Determination of site treatment** You should now have as much information as you are able to obtain from a straightforward site investigation without specialist advice and equipment. Refer to the companion volume, *Site Handbook* of *Roadside Bio-engineering*, Section 1, for instructions on how to determine the site treatment. If the site is large and your investigation shows that the instability is the result of a deep-seated failure, you should contact the Geo-Environmental Unit of the Department of Roads, and discuss the need for a special site investigation.	**Refer to Site Handbook**

CHECK LIST FOR ASSESSING SEVERITY OF SLOPE INSTABILITY

Within each section of the Check List, the conditions are described in order of increasing severity. A site that can be described by the first category in each section is relatively mild and straightforward to stabilise. A site that is described by the last category in each section is a severe problem, often requiring large scale civil engineering works to repair.

Road: _____ **Chainage:** _____ **Observer:** _____ **Date:**

1 LOCATION OF SLIDE
- ☐ Off road alignment but within DOR responsibility
- ☐ Above road - any distance
- ☐ Below road - any distance
- ☐ Between roads, *i.e.* above one road and below another
- ☐ Through road (slide is above and below road)

2 TYPE OF SLOPE AFFECTED
- ☐ Road cutting but not hill slope
- ☐ Hill slope but not road cutting
- ☐ Road cutting plus hill slope
- ☐ Embankment, fill or spoil slope

3 SLOPE CONDITIONS ABOVE SLIDE (above road, if road is at top of slide)
- ☐ Crest of ridge, or gentle slope (less than 35°)
- ☐ Stable, undisturbed hill slope
- ☐ Unstable hill slope. Cracked ground, another landslide or topography that collects water
- ☐ Cut-off drain or take-out drain
- ☐ Irrigation channel (kulo)

4 SLOPE CONDITIONS BELOW SLIDE (or below road, if road is at base)
- ☐ Stable, undisturbed hill slope
- ☐ Intact road at base of slide (road may be buried, but if it is disturbed, road is not at base)
- ☐ Unstable hill slope. Cracks, landslide or topography collecting water
- ☐ Stream

5 GENERAL TYPE OF FAILURE
- ☐ Erosion, rilling or gullying up to 2 m deep
- ☐ Gully more than 2 m deep
- ☐ Mass movement (slide, flow or fall)

6 MATERIAL FORMING ORIGINAL (FAILED) SLOPE
- ☐ Debris, colluvium or alluvium
- ☐ Soft rock (weathering grade 5 or equivalent)
- ☐ Hard rock (weathering grades 1 - 4)
- ☐ Alternating hard and soft rocks

7 FAILURE MECHANISM
- ☐ Erosion (rill, gully or pipe)
- ☐ Plane failure in rock (slide, fall)
- ☐ Collapse (fall with disintegration)
- ☐ Flow or shear failure (slump or slide)
- ☐ Undermining

8 CAUSE OF FAILURE
- ☐ Surface water. Erosion, or soaking of surface: shallow slide/flow
- ☐ Ground water, causing increased pore water pressure at depth
- ☐ Addition of spoil or landslide debris
- ☐ Weathering
- ☐ Undercutting of slope by stream or road cutting

9 DEPTH OF FAILURE
- ☐ Less than 25 mm Erosion
- ☐ 25 - 100 mm }
- ☐ 100 - 250 mm } Slide, slump,
- ☐ 250 - 1000 mm } flow or fall
- ☐ More than 1000 mm }

10 LENGTH OF FAILURE (top to bottom)
- ☐ Up to 15 m
- ☐ 15 - 75 m
- ☐ 75 - 150 m
- ☐ More than 150 m

11 HISTORY OF SLIDE
- ☐ Not moved within the last 5 years
- ☐ Moved within the last 5 years but not this year
- ☐ Moved this year for the first time
- ☐ Moves every year by initial mechanism - diminishing
- ☐ Moves every year by initial mechanism - constant or getting worse

12 LIFE PROGRESSION OF SLIDE
- ☐ Stable slope formed, or will stabilise naturally
- ☐ Further movement expected, by less serious mechanism (post-slide adjustment)
- ☐ Repeated movement expected, by initial mechanism or another equally serious

DETAILS OF THE MAIN BIO-ENGINEERING SPECIES

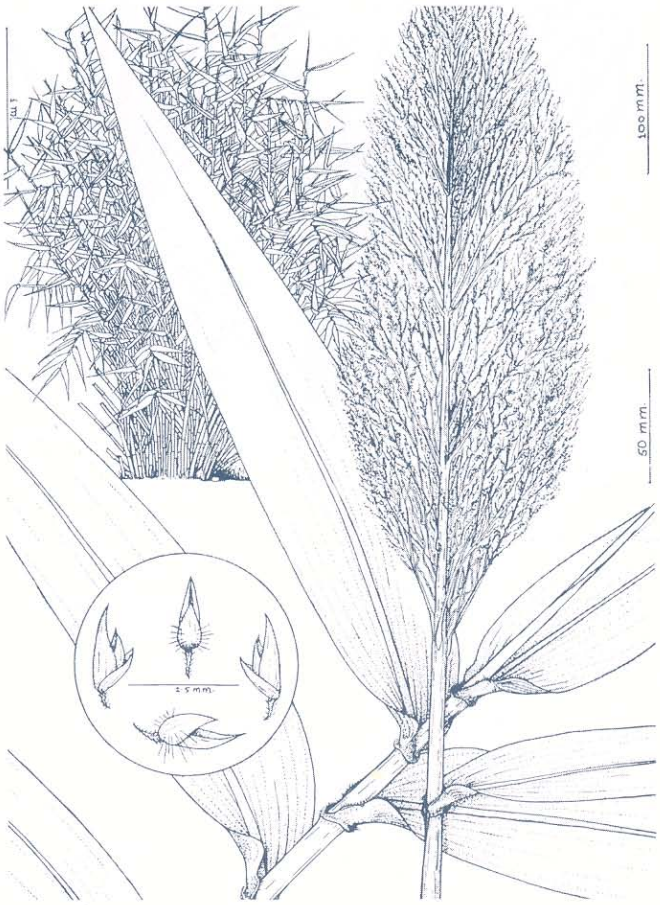
GRASSES

AMLISO

Thysanolaena maxima

Character
Large clumping grass.

Role in bio-engineering
Used in all configurations of planted grass lines.



Description
The grass is used to make kuchos. It is a large-leafed grass closely resembling a bamboo. It has broad culms, perhaps 10 mm in diameter, and leaves about 80 mm wide at their broadest, tapering to a point and about 500 mm long. The leaves are dark green and have a distinctive pattern of indentations running across them about two-thirds of the way up. There are no branches from the stem and the culm is not hollow. The clumps can be a metre or more in diameter. The culms and flower heads are up to 2 metres in height. It has a massive rooting system similar to a small bamboo.

Sites
Terai – 2000 m
Common in the damper areas of forests throughout much of Nepal. Despite its apparent preference for cool, damp areas, it grows well when planted on reasonably dry, stony sites, and in some hot but relatively humid areas. However, it is not as tough as many other grasses.

Propagation
It is easy to propagate from rhizome cuttings, though success is much greater in hot locations. There is also evidence that single-node culm cuttings can be successful if carried out with care. Seeds are very small and seem to be difficult to germinate in nurseries. Seeds are collected between Falgun and Baisakh (March to April).

Cultivation and maintenance
Depending on the site, amliso may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)
Brooms, fodder.

BABIYO

Eulaliopsis binata
Also called sabai grass.

Character
Medium-sized clumping grass.

Role in bio-engineering
Used in all configurations of planted grass lines. Also used for direct seeding.

Description
The grass has very strong fibres and is normally used to make dori. It is a clumping grass with very thin leaves and a coarse feel. It is of medium stature, growing to a height of about 750mm. Babiyo has a characteristic droop, hanging down steep slopes as if laid on purpose as a kind of thatch. Flowers are white.

Sites
Terai – 1500 m
Occurs in the Terai, Churia and lower river valleys throughout Nepal. It grows well on very harsh, hot, dry sites and on steep slopes, even on very stony sites.

Propagation
The most common method of propagation is by splitting out clumps to makes slip cutting. It can also be propagated from seeds. Seeds are collected between Poush and Falgun (January to February).

Cultivation and maintenance
Depending on the site, babiyo may require the following:
- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)
Ropes, paper, fodder.

DHONDE

Neyraudia reynaudiana

Character

Large clumping grass.

Role in bio-engineering

Used in all configurations of planted grass lines. Also used for direct seeding.

Description

A large-stature forest grass. The leaves are thin but grow to about 400 mm in length. The stem is hollow like a bamboo and it has a single small branch from every node. It forms thick clumps of at least 750 mm in diameter and puts up rhizomatous shoots similar to those of bamboos. The seed head is large and bunched but lighter than that of sito.

Sites

Terai – 1500 m

Common in many dry forest types, particularly in eastern Nepal. It grows in the dry, south-facing rain shadow areas where its natural sites are very harsh. Dhonde tolerates the very driest of sites; equivalent to sito in its range.

Propagation

It is easy to propagate from slip cuttings or from seeds. It can also be propagated from culm cuttings. Seeds are collected between Mangsir and Magh (December to January). There are approximately 15,520,000 seeds per kilogramme.

Cultivation and maintenance

Depending on the site, dhonde may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Fodder, poor thatch.

DUBO

Cynodon dactylon

Character

A low, short grass which forms a continuous cover rather than producing clumps.

Role in bio-engineering

Used only for turfing.

Description

A common, invasive creeping grass which forms a tough sward in many bare areas. It has leaves of about 50 to 75 mm in length and is green with a slightly blue hue. It rarely stands more than 100 mm in height, or 50 mm if grazed.

Sites

Terai - 1800 m

Known to produce good growth on fertile sites but is less productive where the site is poorer. It is a secondary coloniser and appears in most areas that are regularly grazed. It is stoloniferous, so spreads well and is invasive in many areas. Dubo tolerates fairly intense grazing.

Propagation

This is most easily done by either root or stolon node cuttings. It grows vigorously from both. Seeds are very difficult to collect.

Cultivation and maintenance

Dubo requires little attention once it is established, although it may require weeding in the first growing season. It does not need to be cut. Protection from grazing is not required, and in fact this may lead to it being overwhelmed by other, larger species.

Uses (other than bio-engineering)

Fodder.

KANS

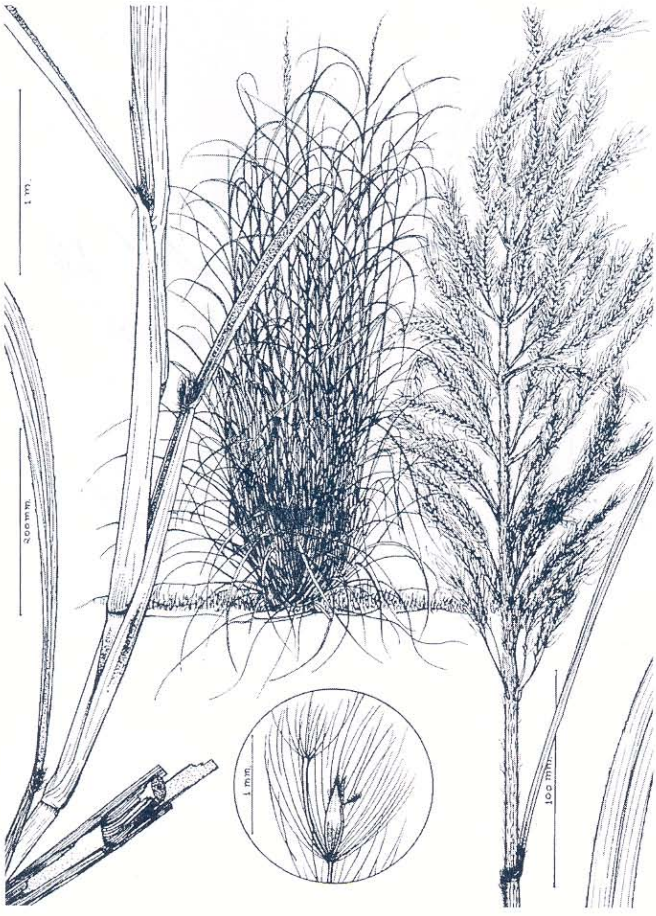
Saccharum spontaneum

Character

Large clumping and spreading grass.

Role in bio-engineering

Used in all configurations of planted grass lines. Also used for direct seeding.



Description

There are two varieties of kans, which have slight differences. One type is a root developer and sends shoots from every node of the roots, but it does not have a proper rhizome. It forms dense clumps, up to about 750 mm in diameter. The other type has a semi-rhizomatous root system but develops mainly by stolons. These can spread rapidly and put roots down from the nodes, although moisture is needed for kans to do this vigorously. The appearance is similar to an enormous spider crawling across the ground. Both types have similar leaves although the stems and leaves are slightly softer in the case of the stoloniferous variety. The leaves are slightly blue in colour, long, very thin and coarse, with a channel running up the middle. The flower heads can be 2 to 3 metres in height and are a brilliant white, making this grass highly distinctive in the autumn.

Sites

Terai - 2000m

The most widespread large indigenous grass in the Terai and lower mountains throughout most of Nepal. It occurs naturally on coarse alluvial soils, including very gravelly and stony areas beside rivers. Kans withstands waterlogging, inundation and severe drought. It also withstands grazing, but will not thrive if the shoots are eaten repeatedly. When planted, it survives well on very hot, dry and harsh sites. It is probably the toughest of the low-altitude grasses, with a deep rooting system and widely spreading stolons.

Propagation

It can be propagated most easily from slip cuttings, and in fact is the easiest of the grasses to grow by this means. It can be grown from stolons if they are available. It grows from seed but not so well. Seeds are collected between Kartik and Poush (November to December).

Cultivation and maintenance

Depending on the site, kans may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Poor fodder, poor thatch.

KATARA KHAR

Themeda species

Character
Large clumping grass.

Role in bio-engineering
Used in all configurations of planted grass lines. Also used for direct seeding.

Description
A large-stature forest grass. The stem is thick, usually up to 10 mm in diameter. The colour makes it distinct from the smaller khar: it has grey colouration where as khar is brownish red when it ripens. The seed head is long (approximately 500 mm) and spiky in appearance; it also curves downwards like dhan (rice).

Sites
Terai - 2000m
It is a widely occurring species and grows in many forest types in its range. However, although katara khar does grow on dry, south-facing slopes in wetter areas, khar is tolerant of much drier sites.

Propagation
It can be propagated from slip cuttings. It also grows from seed. Seeds are collected between Aswin and Mangsir (October to November).

Cultivation and maintenance
Depending on the site, katara khar may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)
Fodder, thatch.

KHAR

Cymbopogon microtheca

Character

Medium large clumping grass.

Role in bio-engineering

Used in all configurations of planted grass lines. Also used for direct seeding.

Description

The grass most commonly used for thatch. It is a medium-stature grass, of a similar size to phurke but not as large as sito or dhonde. Clumps are perhaps 500 mm in diameter and the flower heads are up to 2 metres high. Leaves are similar to those of kans, but are greener (rather than with a blue hue), shorter and curve downwards. But they are thin (less than 5 mm), pointed, have a channel running along them, and are rough to the touch. The flower/seed head has a characteristic multi-spiked appearance. The plant turns a brownish red as the seeds ripen.

Sites

Terai - 2000m

A tough forest grass common throughout the lower Middle Mountains and parts of the Churia range, where it is much used for thatching. It is often cultivated on marginal land by farmers. It grows well on many hot, dry, south-facing slopes. Although not really indigenous to the very driest sites, it grows well on many harsh, dry sites.

Propagation

It can be propagated from slip cuttings. It also grows very easily from seed. Seeds are collected between Mangsir and Magh (December to January). There are approximately 1,681,000 seeds per kilogramme.

Cultivation and maintenance

Depending on the site, khar may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Thatch, fodder (when shoots are young).

KHUS

Vetiveria lawsoni

Also called sinki. This is the north Indian form of *Vetiveria zizanioides*, but is more fertile (*i.e.* produces more viable seeds) and has a different rooting pattern.

Character

Medium-large clumping grass.

Role in bio-engineering

Used in all configurations of planted grass lines.

Description

A medium-stature grass with culms 0.5 to 1.5 metres long and forming dense clumps up to a maximum of 0.5 metres in diameter. There are no rhizomes or stolons. Leaf blades are glossy and a vibrant yellowish green and can easily be split down one side to reveal a white pith; they are up to 750 mm long and 8 mm or less in width; the edges feel rough if stroked downwards. A very thin, darker green line runs up the centre of the leaf, and is a useful distinguishing feature. The roots are many and spongy in mass, with a dominant downward direction.

Sites

Terai - 1500m

Grows naturally along rivers throughout the Nepal Terai and among other grasses in areas prone to seasonal waterlogging. It grows well in dry sites on fill materials but does not grow so well on hard cut slopes. Experience in the Nepal road sector has demonstrated that this species is not as tough and versatile as the widespread literature devoted to vetiver suggests.

Propagation

It is easy to propagate by root splitting. It seeds, but not prolifically, and can also be grown from them. Seeds are collected between Aswin and Mangsir (September to November). There are approximately 1,712,000 seeds per kilogramme.

Cultivation and maintenance

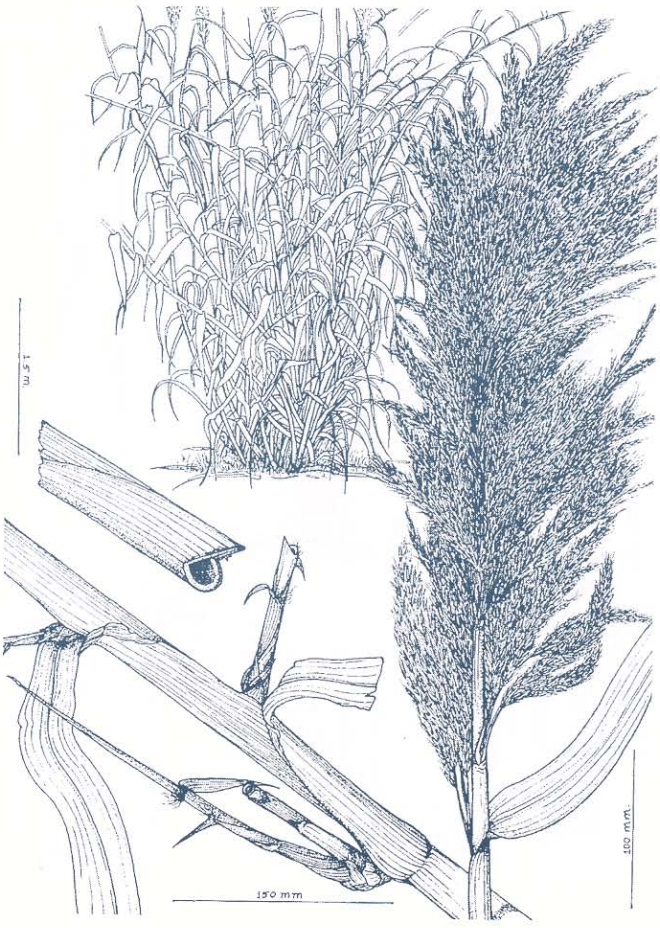
Depending on the site, khus may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Fodder, poor thatch.



NARKAT

Arundo clonax

Character

Large clumping and spreading grass.

Role in bio-engineering

Used in all configurations of planted grass lines.

Description

A large-stature forest grass. The stem is hollow and similar in appearance to bamboo but less woody. The leaves are a pea green colour, thick, pointed and about 15 mm wide. They grow opposite each other in a regular and distinct pattern, with the ends bending downwards in a semicircular arc.

Sites

Terai - 1500m

It grows on hot, south and south-west facing slopes. In the Terai, it grows in sal (*Shorea robusta*) forest. It thrives most vigorously in wet and waterlogged sites.

Propagation

It can be propagated easily from seed, slip and stem cuttings. For stem cuttings, material more than two years old with heavy branches should be used. Seeds are collected between Mangsir and Magh (November to January).

Cultivation and maintenance

Depending on the site, narkat may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Poor fodder.

PADANG BANS

Himalayacalamus hookerianus

Character

Large clumping grass. A small stature bamboo.

Role in bio-engineering

Used in all configurations of planted grass lines.

Description

A small stature bamboo with blue culms and distinctive culm sheaths which narrow from the base upwards. It tends to form clumps rather than spreading like the other small bamboos.

Sites

1500 - 2500 m

Prefers cool, damp sites with some shade and moisture. It is not as drought resistant as the large bamboos.

Propagation

It is easily propagated by the traditional bamboo planting method. Seeding is very rare.

Cultivation and maintenance

Depending on the site, padang bans may require the following:

- weeding;
- protection from grazing.

Bamboos should not be cut completely like other grasses, but partial cutting can be done in Magh or Falgun.

Uses (other than bio-engineering)

Weaving.

PHURKE

Arunduella nepalensis

Character

Medium sized clumping grass.

Role in bio-engineering

Used in all configurations of planted grass lines. Also used for direct seeding.

Description

Smaller in stature than many of the other forest grasses, this grows to a height of only about 1.5 m. The leaves are similar to dhonde but with a rough edge; they are pointed and there is an angle of about 35 degrees between the stem and the leaves. The culm is hollow and only has branches from the nodes on material of two or more years in age. Also, the seed head is finer than that of sito or dhonde, and the seed husks are rougher. Clumps do not exceed 0.5 metres in diameter.

Sites

700 - 2000 m

Grows naturally on relatively damp south-west to north facing slopes. It is tough and colonises landslides, therefore growing in harsh, stony sites. It probably does not do well on hot sites in the full sun.

Propagation

This is easily done either by splitting clumps into slip cuttings, or by seed. Seeds are collected between Mangsir and Magh (December to January). There are approximately 1,809,000 seeds per kilogramme.

Cultivation and maintenance

Depending on the site, phurke may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)
Thatch, fodder.

SITO

Neyraudia arundinacea

Character

Large clumping grass.

Role in bio-engineering

Used in all configurations of planted grass lines. Also used for direct seeding.

Description

A large-stature grass very similar in overall appearance to dhonde but which occurs under wetter climatic conditions. The stem is not hollow, but is thicker than dhonde (up to about 20 mm), and the leaves are wider and longer. When the stem nodes are more than two years old, roots and branches can begin to emerge from them. It reaches a height of about 2.5 metres; clumps grow to be about 0.75 metres in diameter. Young shoots are poisonous to animals, but are grazed when there is no other grass.

Sites

Terai - 1500m

Common in many forest types in the damper parts of Nepal. Sito grows in harsh sites, including south-facing slopes, but in areas of higher rainfall. It grows in dry sites if planted, and is the equivalent to dhonde in its range, occurring in similar sites but in areas of higher rainfall.

Propagation

It propagates readily from slip cuttings, culm cuttings or seed. Seeds are collected between Mangsir and Magh (December to January). There are approximately 16,390,000 seeds per kilogramme.

Cultivation and maintenance

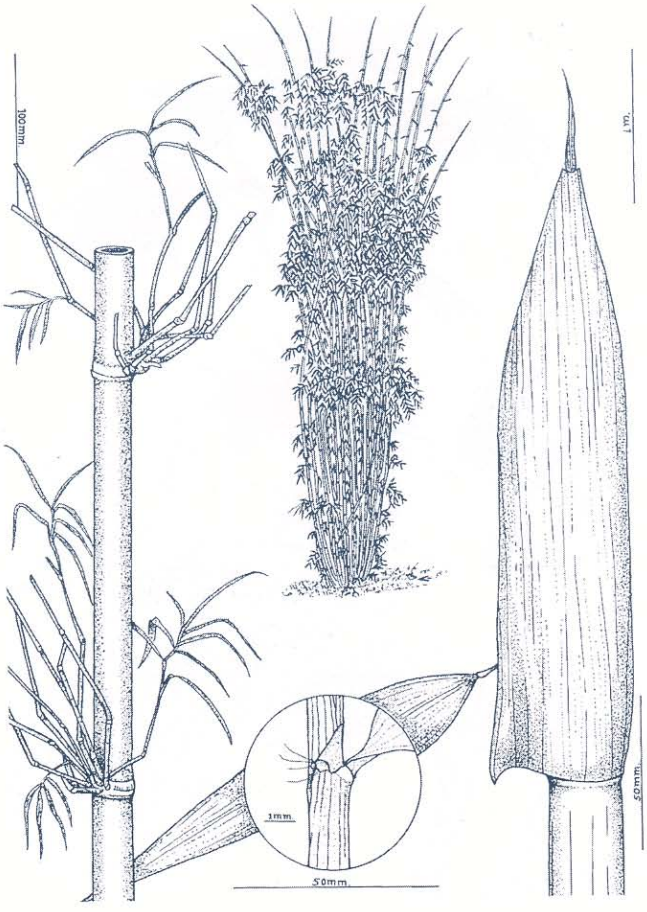
Depending on the site, sito may require the following:

- weeding;
- protection from grazing.

It should normally be cut in Magh or Falgun.

Uses (other than bio-engineering)

Poor thatch, poor fodder.



TITE NIGALO BANS

Drepanostachyum intermedium

Character

Large spreading grass. A small stature bamboo.

Role in bio-engineering

Used in all configurations of planted grass lines.

Description

A small stature bamboo. Leaf sheaths are hairy and culm sheaths narrow from about half way up. A spreading, rather than clumping bamboo.

Sites

1000 - 2500 m

Common throughout the middle mountains. This is the most resilient small-stature bamboo. It is found on relatively hot, dry and exposed banks, and in rocky sites in its range. But it is not as resistant to drought as the larger bamboos and grows best in damp, shady sites.

Propagation

It is easily propagated by the traditional bamboo planting method. Seeding is very rare.

Cultivation and maintenance

Depending on the site, tite nigalo bans may require the following:

- weeding;
- protection from grazing.

Bamboos should not be cut completely like other grasses, but partial cutting can be done in Magh or Falgun.

Uses (other than bio-engineering)

Weaving, fodder.

SHRUBS AND SMALL TREES

ARERI
Acacia pennata

Character
Small thorny tree, up to 5 m.

Role in bio-engineering
Used for shrub and tree planting or shrub and tree direct seeding.

Description
A small tree or large shrub, with either a single trunk or branches rising from ground level. Rarely greater than 5 metres in stature. It is extremely thorny and the branches snap very easily.

Sites
500 - 1500 m
Occurs throughout Nepal on disturbed land in the Churia and lower mountains. It colonises landslides naturally, but tends to be found more in damp sites or areas of higher rainfall. It is very resilient and grows on harsh sites and in very stony places, although it will not thrive on the very driest sites where khayer (*Acacia catechu*) will grow..

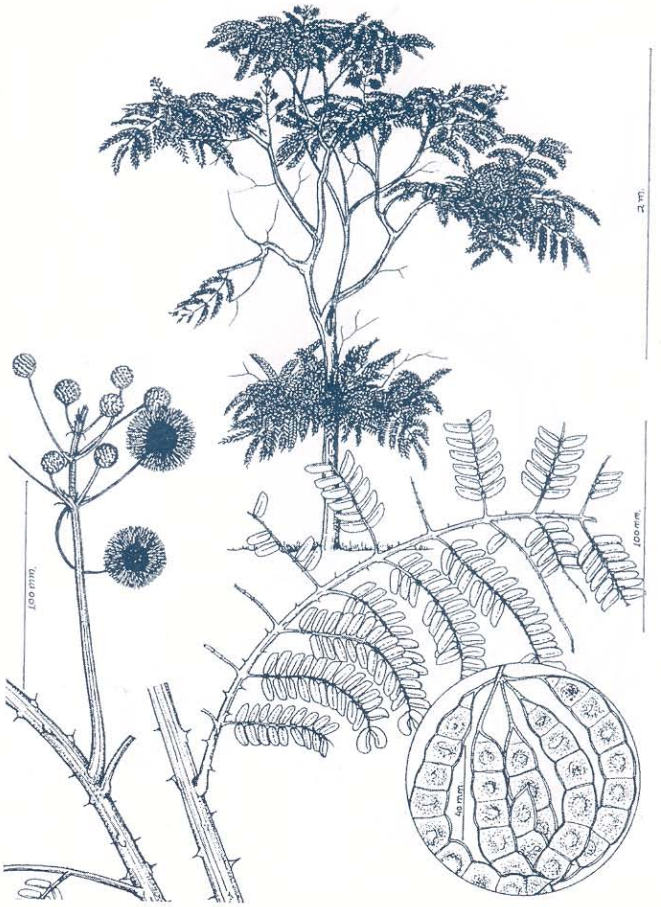
Propagation
It seeds abundantly and is easy to propagate by this method. Direct sowing on site is usually successful. Seeds are collected between Kartik and Poush (November to December). There are approximately 36,000 seeds per kilogramme; they remain viable for about 12 months.

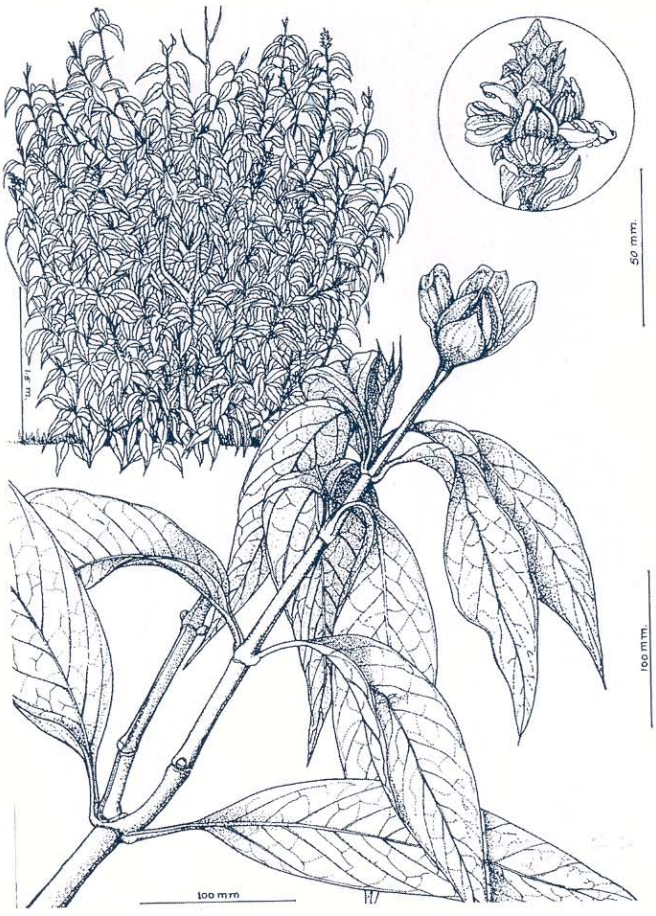
Cultivation and maintenance
Depending on the site, areri may require the following:

- weeding;
- protection from grazing in the first year; after this it is not damaged by grazing.

Thinning should be carried out when the plantation gets too dense. Areri can be lopped heavily but full coppicing or pollarding tends to kill it.

Uses (other than bio-engineering)
Normally none, although it can be used for hedging.





ASSURO

Adhatoda vasica

Character

Shrub up to 3 m high.

Role in bio-engineering

Used for brush layering, palisades, live check dams and fascines.

Description

A shrub which forms a dense bush up to 3 metres high. The leaves are a brilliant green, showing up distinctly during the late dry season. It has stems, which are shiny, and green when young but change to be white when they mature.

Sites

Terai - 1000m

It occurs in the Bhabar sal forest and the Churia. It appears to be an understorey plant and is certainly tolerant of shade. But although it grows best in damp, shady sites, it will also survive in dry, stony areas.

Propagation

Hardwood stem cuttings can be taken and have a high success rate. They can be planted in a nursery or directly on site. Cuttings can be planted at any angle, but upside down is not recommended.

Cultivation and maintenance

Depending on the site, assuro may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Assuro can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Compost, medicines, hedging.

BAINSH

Salix tetrasperma

Character

Tree up to 15 m high.

Role in bio-engineering

Used for brush layering, palisades, live check dams and fascines.

Description

A fodder tree grown mostly at higher altitudes Leaves are feathery , both in shape and the way they hang and flutter in a breeze; the undersides of leaves are white. They grow in a regular pattern along the branches. Branches are long and thin, and hang down like hair.

Sites

Terai - 2700m

Bainsh grows naturally along stream channels and it is in this situation where it can mostly be found. It grows in drier locations when planted but only thrives in damp and north-facing sites It should not be used in dry sites below 2000 metres.

Propagation

Hardwood stem cuttings can be taken and have a high success rate in damp sites. They can be planted in a nursery or directly on site.

Cultivation and maintenance

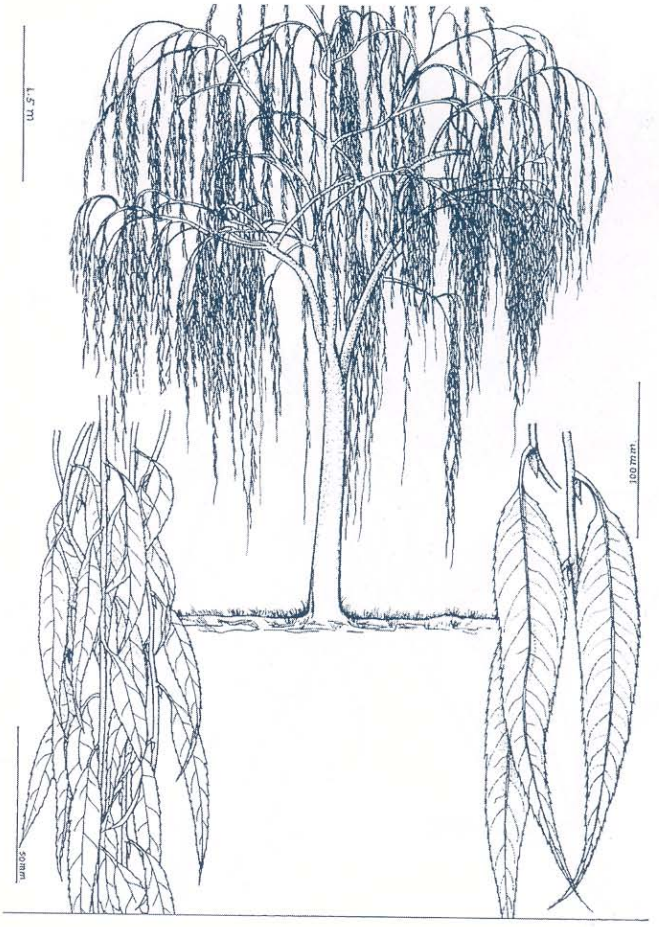
Depending on the site, bainsh may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Bainsh can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Weaving, fodder, small timber.



BHUJETRO

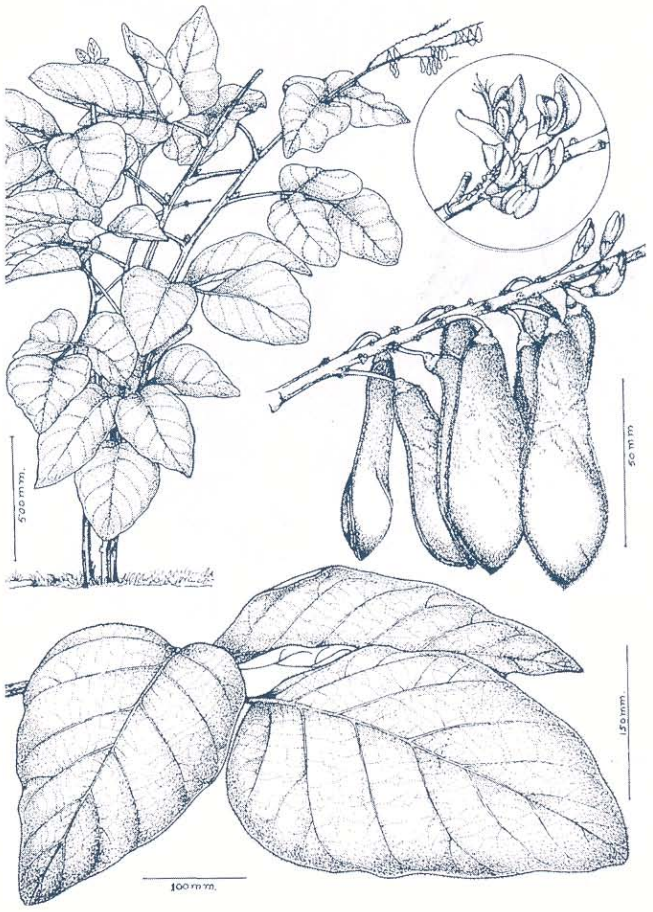
Butea minor

Character

Shrub up to 4 m high.

Role in bio-engineering

Used only for shrub and tree direct seeding.



Description

A straggly plant with furry, brown stems and large, fleshy triple leaves at the end of each. Flowers during the early monsoon rains are a brilliant red. Plants have between one and six stems, but are never more than 4 metres high. The roots mostly grow downwards, with a dominant tap root, and they are exceptionally large and strong for the size of the plant. The stem dies back in the winter and the plant sends out complete new shoots very early in the monsoon.

Sites

500 - 1500 m

Occurs naturally in areas of higher rainfall in the Churia range and lower mountains of eastern Nepal. It grows well when planted in dry, south-facing sites and in dry, stony ground. It also grows well in rocky crevices in its climatic zone. But it does not perform well in the very driest places and hardest materials. It has been planted up to 2000 metres in warm sites in the upper Trisuli valley.

Propagation

It seeds in large numbers, with one large seed in each pot. Germination of six-month old seed is nearly 100 per cent and, because of the large tap root, it is best not transplanted. Direct sowing on site, with the seed still in its pod, gives excellent results. Seeds are collected between Kartik and Poush (November to January). There are approximately 450 seeds per kilogramme; they remain viable for about 18 months.

Cultivation and maintenance

Once the seed has been sown, the only maintenance required is protection from grazing while the shoots are young. The stem dies back in the winter and the plant sends out complete new shoots very early in the monsoon, so thinning is not required.

Uses (other than bio-engineering)

Animal bedding, umbrellas, meat packing.

DHANYERO

Woodfordia fruticosa

Character

Shrub up to 3 m high.

Role in bio-engineering

Used only for shrub and tree planting.

Description

A rather untidy, straggling shrub which reaches a maximum height of about 3 metres. Leaves are smooth and pointed, and grow opposite each other in a regular pattern. The flowers grow from nodes on the stem and are a brilliant red.

Sites

Terai - 1500m

It occurs mostly on the drier Churia slopes and on dry sites in the lower middle mountain valleys, and is very common throughout Nepal. On some south-facing slopes it forms almost pure stands. Dhanyero grows in the very harshest of hot, dry and very steep sites, including rocky slopes.

Propagation

Seeds are very small but germinate easily in a carefully prepared nursery seed bed. It cannot be grown from hardwood cuttings. Seeds are collected between Falgun and Baisakh (March to April). There are approximately 1,000,000 seeds per kilogramme; they remain viable for about 12 months.

Cultivation and maintenance

Depending on the site, dhanyero may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Dhanyero can be lopped heavily, and once the plant is established, thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Bedding, firewood, wine (from flowers).

DHUSUN

Colebrookea oppositifolia

Character

Shrub up to 2 m high.

Role in bio-engineering

Used mainly for shrub and tree planting.

Description

A small shrub growing to a height of about three metres. It has pointed leaves about 100 mm long, with serrated edges and a spongy feel. The flowers are white, and are also spongy.

Sites

Terai - 1000m

A constituent of the drier forest types of the Bhabar and Siwalik zones. It also grows on hot, dry slopes where there is little else, and is probably a coloniser of such sites. Dhusun grows reasonably well when planted in the hottest places in the Churia range.

Propagation

The seeds are very small but can be germinated readily in a carefully prepared seed bed. Seeds are collected between Falgun and Chaitra (March). There are approximately 1,000,000 seeds per kilogramme; they remain viable for about 12 months.

Cultivation and maintenance

Depending on the site, dhusun may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense.

Uses (other than bio-engineering)

Medicine.

KANDA PHUL

Lantana camara
Also called sutkeri phul.

Character
Shrub up to 2 m high.

Role in bio-engineering
Used mainly for brush layering, palisades, live check dams and fascines.

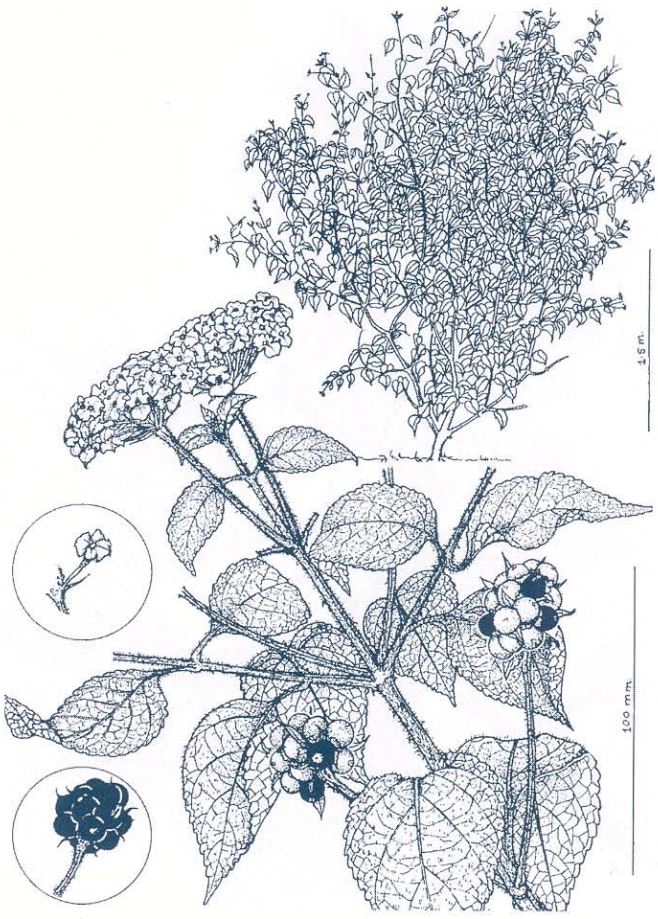
Description
A bushy shrub which forms dense thickets. Its maximum height is about 2 metres. Leaves are coarse and the stems thorny. Flowers vary, individual plants having either yellow, white, pink or mauve flowers.

Sites
Terai - 1750m
An invasive weed on many dry slopes throughout the lower mountains; common around towns and in other areas disturbed by man; it grows when planted on many dry, stony and degraded sites.

Propagation
Although it seeds prolifically, the seeds are difficult to germinate under nursery conditions. Stem cuttings, however, are usually successful. They should ideally be between 10 and 30 mm in diameter and at least 300 mm long. Cuttings buried in trenches (as fascines) are usually more successful than normal cuttings.

Cultivation and maintenance
Kanda phul is slow to establish. Weeding may be required. The shrub is resistant to grazing and if used properly can make a good but thick hedge. It has no understorey and gullying can start underneath even dense stands of bushes. However, careful thinning and coppicing reduces erosion to some extent.

Uses (other than bio-engineering)
Poor ornamental, hedging.



KERAUKOSE

Indigofera atroturpurea

Character

Tree up to 8 m high.

Role in bio-engineering

Used for shrub and tree planting or shrub and tree direct seeding.

Description

A small stature tree with irregular branching and rising to a maximum height of about 8 metres. The bole and branches are slender. Leaves are smooth, spear-shaped (lanceolate) and about 60 mm long by 15 mm wide. The leaf tips are sometimes round rather than pointed. Flowers are generally white or purple and occur around and near the ends of the stems. The fruit hangs in pods about 50 mm long, like dal, with 10 to 25 seeds per pod.

Sites

Terai - 2000m

It colonises landslides and other disturbed land in the wetter areas of the Siwaliks and southern Mahabharat. It seems to grow well in almost every site in which it is planted, within its altitudinal range. It does well on very dry and hot south-facing Churia slopes, and on dry, stony fill material.

Propagation

The seeds can be germinated easily in the nursery, or sown direct to site. Although early growth can be slow in the nursery, it speeds up once the seedling has reached a height of about 400 mm. It cannot be propagated from hardwood cuttings. Seeds are collected between Kartik and Poush (November to January). There are approximately 94,000 seeds per kilogramme; they remain viable for about 12 months.

Cultivation and maintenance

Depending on the site, keraukose may require the following:

- weeding;
- protection from grazing in the first few years: after this, keraukose is resistant to grazing even though it is leguminous.

Thinning should be carried out when the plantation gets too dense. It can be lopped heavily and pollarded (except on very dry sites, but full coppicing tends to kill it).

Uses (other than bio-engineering)

Firewood, shade tree (particularly in tea gardens in the Terai of West Bengal).

KETTUKE

Agave americana

Character

Large cactus; sub-species with and without thorns.

Role in bio-engineering

Used mainly for shrub and tree planting.

Description

A cactus growing so that almost the entire visible plant comprises only leaves. A mass of fibrous, succulent leaves grow upwards to a maximum height of about 1.5 metres. They usually have a bluish colour. Leaves are up to 100 mm wide and 20 mm thick. In thorny varieties, the leaf edges and tips are fringed with upwards-pointing thorns.

Sites

Terai - 2000m

Kettuke grows on hot, dry, south-facing slopes. It is not found in damp or shady sites, and seems to require full sunlight to thrive. Throughout its range, it grows in the driest sites available.

Propagation

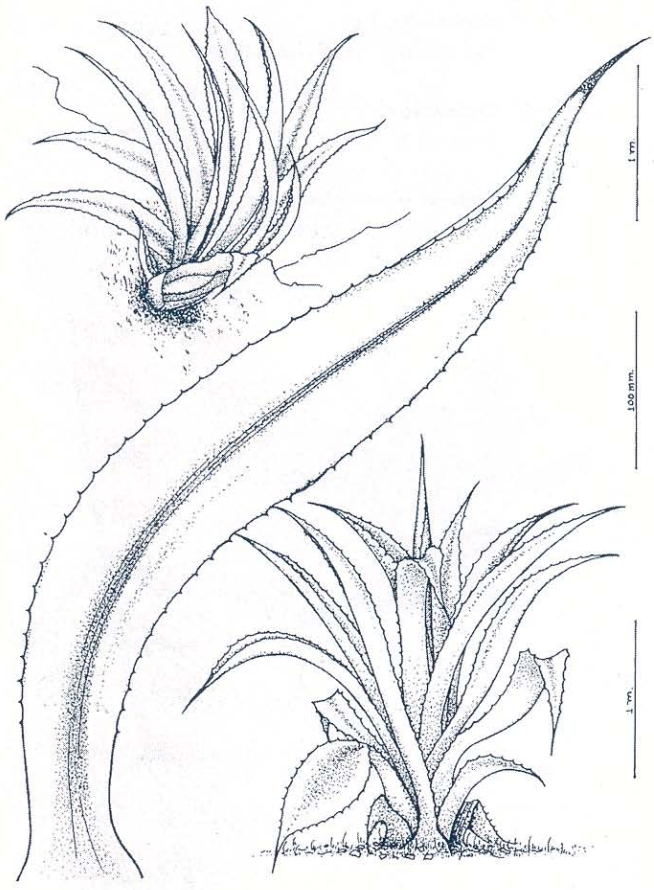
Seeds are rare. It is grown by separating a section of rootstock or a sucker (a small shoot coming up from the roots of a bigger plant). There is no need of growing these on in a nursery unless large, strong plants are needed.

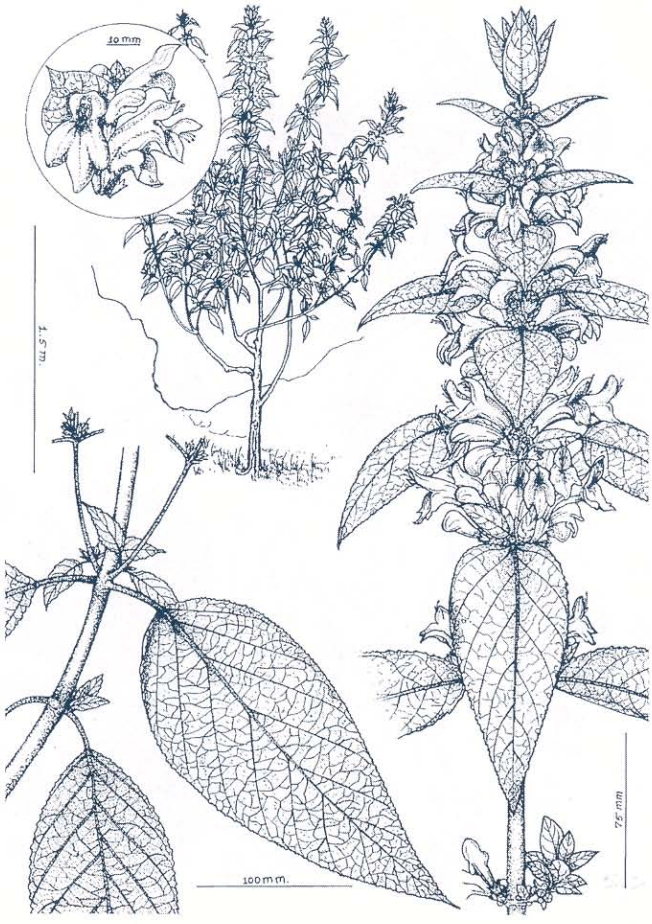
Cultivation and maintenance

Once established, kettuke needs no maintenance. It is resistant to grazing.

Uses (other than bio-engineering)

Hedging.





NAMDI PHUL

Colquhounia coccinea

Character

Shrub up to 3 m high.

Role in bio-engineering

Used for brush layering, palisades, live check dams and fascines.

Description

A small shrub with medium-sized, pointed leaves and striking red flowers in Mangsir and Poush. The leaves are spongy and grey on the underside.

Sites

1000 - 2000 m

Namdi phul occurs in damper sites in its range. It grows best on north-facing sites. It tends to grow extremely well on colluvium and debris slopes.

Propagation

It can be propagated very easily from hardwood stem cuttings.

Cultivation and maintenance

Depending on the site, namdi phul may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Namdi phul can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

None known.

SARUWA/BIHAYA

Ipomoea fistulosa

Character

Recumbent shrub.

Role in bio-engineering

Used for brush layering, palisades, live check dams and fascines.

Description

A low-lying shrub with straggling stems up to 3 metres long. The stems have few branches and clumps of leaves at the ends. Leaves are shaped like a heart with an extended point. The flower is from pale pink to purple in colour and shaped like a trumpet. Mature clumps of this weed are extremely dense and impenetrable to animals.

Sites

Terai - 1500m

An invasive weed growing abundantly in wet, marshy depressions in the Terai and lower hill valleys; frequently found in the old borrow pits beside road embankments. It grows well when planted on hot, dry sites, but only if the soil is loose: therefore it can be highly successful on fill material but may fail completely after a promising first season on cut slopes. It needs full sunlight to grow and cannot tolerate shading.

Propagation

It takes very easily and rapidly from stem cuttings. Since there is such a ready supply of material in the Terai, there is little point in collecting seed.

Cultivation and maintenance

Depending on the site, saruwa needs little maintenance. It grows vigorously and so does not require weeding. Protection from grazing may be required when young; after the first growing season it is resistant to grazing. Thinning should be carried out when the plantation gets too dense. Saruwa can be lopped heavily, and thinning can be achieved by full coppicing. It will die out completely if it is shaded.

Uses (other than bio-engineering)

Poor firewood when there are no alternatives.

SIMALI

Vitex negundo

Character

Small tree, up to 6 m high.

Road in bio-engineering

Used for brush layering, palisades, live check dams and fascines.

Description

A small, vigorous tree growing to a maximum height of about six metres. Branches tend to be heavy, giving the plant an irregular form. Leaves are smooth and pointed and, characteristically, in groups of three or five. Flowers are white, later becoming pink, growing upright at the ends of the stems.

Sites

Terai - 1750m

A common small tree throughout the lower mountains. It occurs naturally along rivers and in gullies where it grows on very stony ground. Despite this obvious preference for moist, shady places, it grows when planted on dry, stony sites and on hot, dry road cuts.

Propagation

Seeds are very small and difficult to germinate under nursery conditions. Hardwood stem cuttings give excellent results, however. Material should ideally be between 10 and 30 mm in diameter, but cuttings up to 50 mm are also successful. They should be at least 300 mm long, although cuttings of up to 1.2 metres have been successful. They can be planted direct on site any way up, but upside down is not recommended.

Cultivation and maintenance

Depending on the site, simali may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Simali can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Hedges, firewood.

TILKA

Wendlandia puberula

Character

Tree up to 10 m high.

Role in bio-engineering

Used for shrub and tree planting.

Description

A medium sized tree growing to about 10 metres in height. Leaves are fairly large and fleshy. The flower is white.

Sites

Terai - 1500m

It occurs mostly on the drier Siwalik slopes and on dry sites in the lower mountain valleys. On some south-facing slopes it forms almost pure stands. It will grow moderately well on the harshest of hot and dry sites and on hard clay soils.

Propagation

Seeds are small but germinate easily in a carefully prepared nursery seedbed. Tilka cannot be raised from hardwood cuttings. Seeds are collected between Magh and Chaitra (February to March). There are approximately 1,000,000 seeds per kilogramme; they remain viable for about 12 months.

Cultivation and maintenance

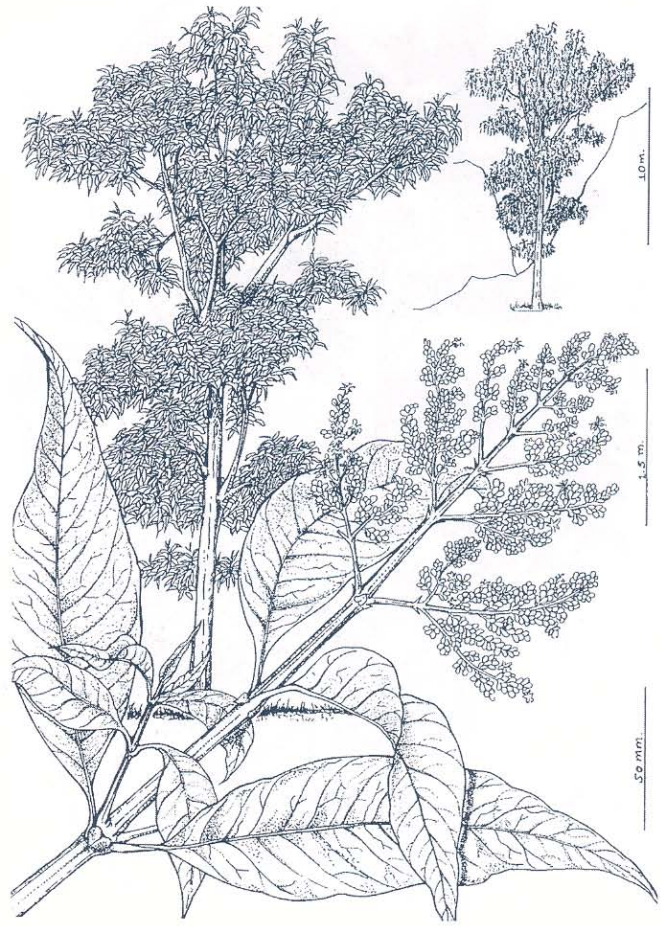
Depending on the site, tilka may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Tilka can be lopped heavily, and once the plant is established, thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Firewood.



LARGE TREES

BAKAINO

Melia azedarach
Persian lilac

Character
Medium to large deciduous tree.

Role in bio-engineering
Large tree planting. Can also be sown directly on site (direct seeding or broadcasting).

Description
The trunk and branches of this tree are very smooth. They have a bluish hue when young, turning to brown as they mature. The trunk is usually quite straight. Branches are relatively few and are thin, straight and brittle. The leaves are similar to neem (pointed with serrated edges) and come in composite groups. The fruit hangs in clusters, with one seed per fruit.

Sites
Terai – 1800 m
A fast-growing tree which thrives in many warm sites. Although a good soil is required for best growth, it survives well on shallow, stony, infertile and very dry soils. It does much better on fill materials rather than on cut slopes.

Propagation
Propagation is by polypot seedlings raised from seed in a nursery. There are 1,200 seeds per kg, collected between Mangsir and Falgun (November to March). They remain viable for about 12 months.

Cultivation and maintenance
Depending on the site, bakaino may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Bakaino can be lopped heavily, and once the tree is established, thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)
Timber, firewood.

CHILAUNE

Schima wallichii

Character

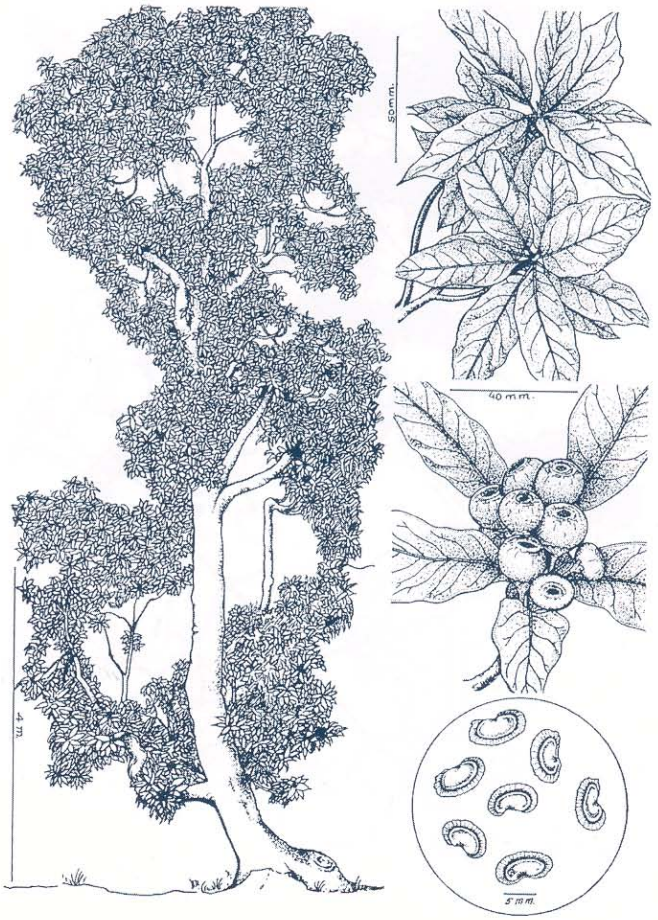
Large deciduous tree.

Role in bio-engineering

Large tree planting.

Description

Leaves are relatively large, with a serrated edge and shiny top. The bark is thick and covered in hairs that are very itchy. The flower buds are rounded and white, but open to reveal a bright yellow centre. The fruit forms a hard spherical coat and, when dried, opens into four equal divisions. The seeds are white with thin platy wings.



Sites

900 – 2000 m

Chilaune, with various species of katus (*Castanopsis*), forms the dominant forest on northern aspects in its altitude range. It grows best on moist sites and is usually found on south-facing slopes only in areas of high rainfall. However, it can survive a certain amount of drought. It can tolerate shade, and often starts to appear in plantations of other species, particularly of salla and utis. Chilaune can also regenerate very well.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 160,000 seeds per kg, collected between Magh and Chaitra (January to April). They remain viable only for about 6 months.

Cultivation and maintenance

Depending on the site, chilaune may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Chilaune can be lopped heavily, but should not be coppiced or pollarded.

Uses (other than bio-engineering)

Firewood, timber.

DABDABE

Garuga pinnata

Character

Large deciduous tree.

Role in bio-engineering

Large hardwood cuttings (truncheon cuttings) are used as part of live check dams.

Description

A common fodder tree. The trunk is usually straight, white and has relatively rough bark. The leaves are regular and grow opposite each other. The leaves are large, long and pointed.

Sites

Terai – 1300 m

Dabdabe is associated with sal (*Shorea*) and banghi (*Anogeissus*) forests. It does grow on stony and fairly dry sites, but is much better in damp situations and often occurs near streams.

Propagation

For bio-engineering purposes it is normally propagated as a large hardwood cutting or truncheon cutting: these are typically 2 metres in length. However, it can also be propagated from seed and raised in polypots in the nursery. There are 4,000 seeds per kg and they are collected between Ashad and Bhadra (June to September). They remain viable for about 12 months.

Cultivation and maintenance

Depending on the site, dabdabe may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Dabdabe can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Timber, fodder.

GOBRE SALLA

Pinus wallichiana, Blue pine

Character

Large coniferous tree.

Role in bio-engineering

Large tree planting. Can also be sown directly on site (direct seeding or broadcasting).

Description

The higher-altitude pine. Above about 1900 metres, it is likely to be the only pine found. It has long (about 200 mm) bluish needles, which occur in clusters of five. The bark is smooth (chillo) and shiny.

Sites

1800 – 3000 m

Gobre salla has a natural tendency towards warm, dry sites and within its altitude range grows on most of the driest sites. It occurs at higher altitudes in the drier inner valleys. It is also found in north-facing gullies, but in general does poorly in damp sites.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 22,500 seeds per kg, collected between Aswin and Mangsir (October to November). They remain viable for about 12 months.

Cultivation and maintenance

Depending on the site, gobre salla may require:

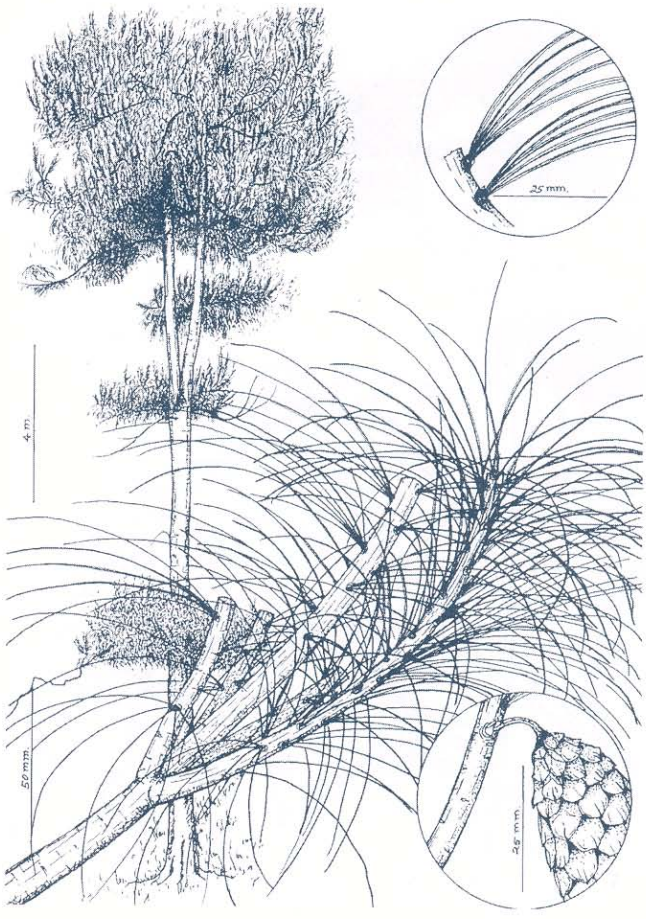
- weeding (in the first two or three growing seasons: dense grass around the trunk is particularly harmful);
- protection from grazing (until it gets out of the reach of animals).

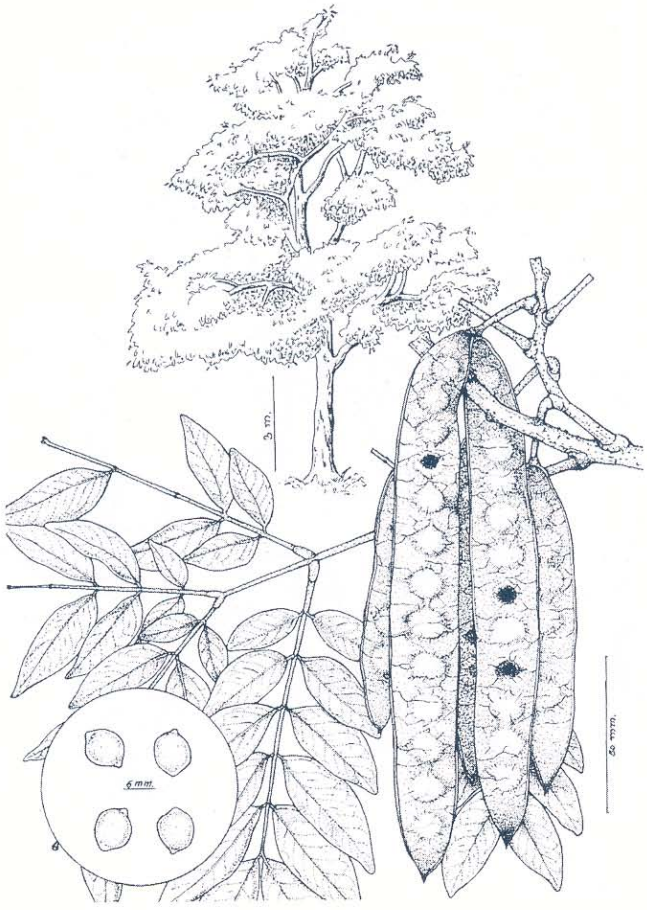
Dense plantations should be thinned. Small branches can be lopped, but pine trees should not be coppiced or pollarded.

Since gobre salla is a pioneer species, it should not be grown as the main species on a site for more than about five years. Vegetation enrichment should be used to grow up other species between the pine trees, with the aim of removing all pines by 10 years after the first planting.

Uses (other than bio-engineering)

Timber, firewood.





KALO SIRIS

Albizia lebbeck

Character

Medium-sized deciduous tree.

Role in bio-engineering

Large tree planting.

Description

A medium-sized tree commonly used for firewood. The trunk is normally straight. Leaves are oval with a slight point, and grow in even numbers (*i.e.* there are always 2, 4, 6 or 8). The stems of young trees are brittle, and usually covered in yellowish-brown spots.

Sites

Terai – 1200 m

Kalo siris grows naturally in harsh sites, since it is a constituent of the sissoo-khayer riverine forest and the sal-saaj forest in the Siwaliks. It is tolerant of droughts and grows on infertile soils. It has been used extensively in India for erosion control. It does not withstand waterlogging, and so should not be planted where drainage is a problem.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 5,000 seeds per kg, collected between Mangsir and Magh (November to January). They remain viable for at least five years.

Cultivation and maintenance

Depending on the site, kalo siris may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Kalo siris can be lopped heavily, and once the tree is established, thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Timber, firewood, fodder.

KHANYU (KHOSRO)

Ficus semicordata
Fig

Character
Small stature, heavy branching.

Role in bio-engineering
Large tree planting. Can also be sown directly on site (broadcasting only).

Description
A medium stature tree with distinctive semicordate leaves. The fruits grow from the trunk on aerial roots. It is distinguished from var. *montana* (rai khanyu) by its coarser leaves and white (rather than red) leaf veins.

Sites
Terai – 2000 m
A natural coloniser of bare and often very rocky sites. Khanyu is often the first tree species to appear on disturbed ground. It can withstand considerable drought, but also grows well in damp sites. Like most colonisers, full light is required, and it cannot tolerate shade. It is one of the most versatile trees for bio-engineering.

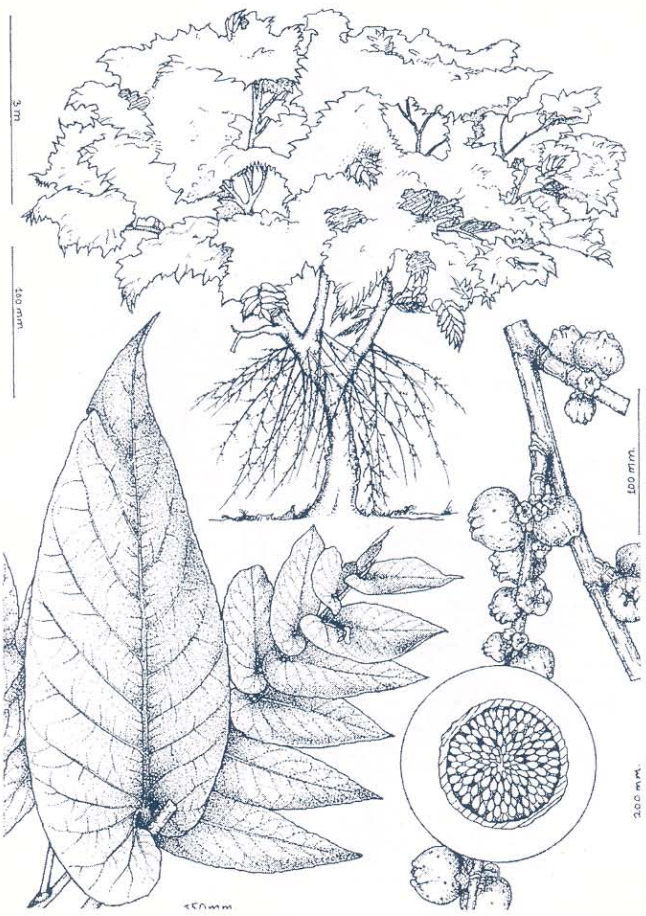
Propagation
Propagation is normally by polypot seedlings raised from seed in a nursery. There are 1,500,000 seeds per kg, collected between Shrawan and Aswin (July to October). They remain viable for only about 6 months.

Cultivation and maintenance
Depending on the site, khosro khanyu may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Khosro khanyu can be lopped heavily, and once the tree is established, thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)
Fodder.



KHAYER

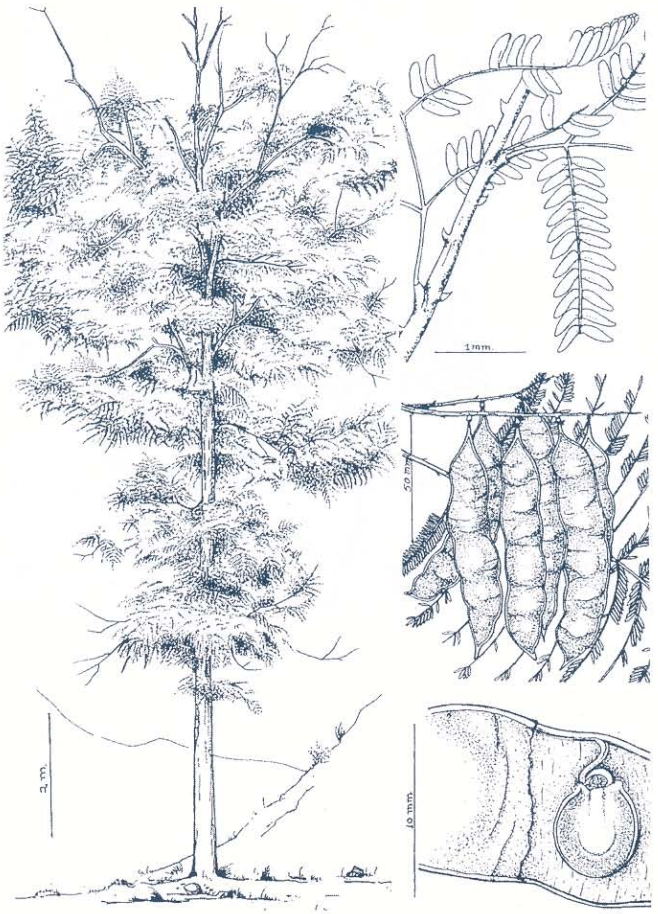
Acacia catechu

Character

Large, thorny tree.

Role in bio-engineering

Large tree planting. Can also be sown directly on site (direct seeding or broadcasting).



Description

A full stature tree with thorny branches and small, composite leaves. The trunk is never straight. Leaves are small (< 10 mm), arranged opposite each other. The thorns curve backwards.

Sites

Terai – 1000 m

Of any common tree found in Nepal, khayer is the most tolerant of excessively hot, dry sites. It needs full sunlight and does not grow in shady locations. But it will grow in any stony or gravelly soil, however dry, or in hard, clayey or calcareous residual soils. It withstands waterlogging and, as a major constituent of riverine forests, it can tolerate deep inundation. Away from the Terai and Siwalik river fringes, khayer grows in almost pure stands on dry, south-facing slopes in deep river valleys and other rain shadow areas: in all sites where it grows naturally, it is an indicator of low rainfall and hot summer temperatures.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 30,000 seeds per kg, collected between Poush and Falgun (January to February). They remain viable for about 2 years.

Cultivation and maintenance

Depending on the site, khayer may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Khayer can be lopped, and once the tree is established, thinning can be achieved by coppicing; however, it will not re-grow if the shoots are shaded by other plants.

Uses (other than bio-engineering)

Firewood, fodder, extracts.

LANKURI

Fraxinus floribunda
Ash

Character
Large deciduous tree.

Role in bio-engineering
Large tree planting.

Description
A large tree with a straight, white trunk. The flowers are white and the leaf form in groups of three.

Sites
1200 – 2700 m
Lankuri grows on a wide range of sites and is one of the best survivors on poor materials. It tolerates limestone as well as acidic soils. Young seedlings need full light, and will not grow in shady locations.

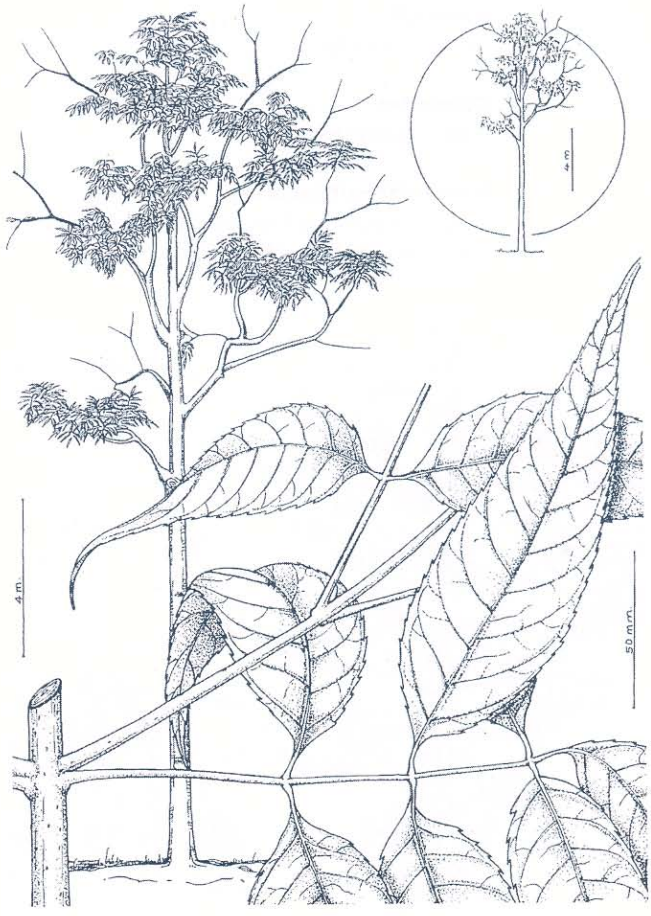
Propagation
Propagation is by polypot seedlings raised from seed in a nursery. There are 60,000 seeds per kg, collected between Aswin and Poush (September to January). Green seed should be kept moist and sown immediately. If the seed is brown when collected, or if green seed dries out, it will not germinate until the spring after the next monsoon, but remains viable for three years.

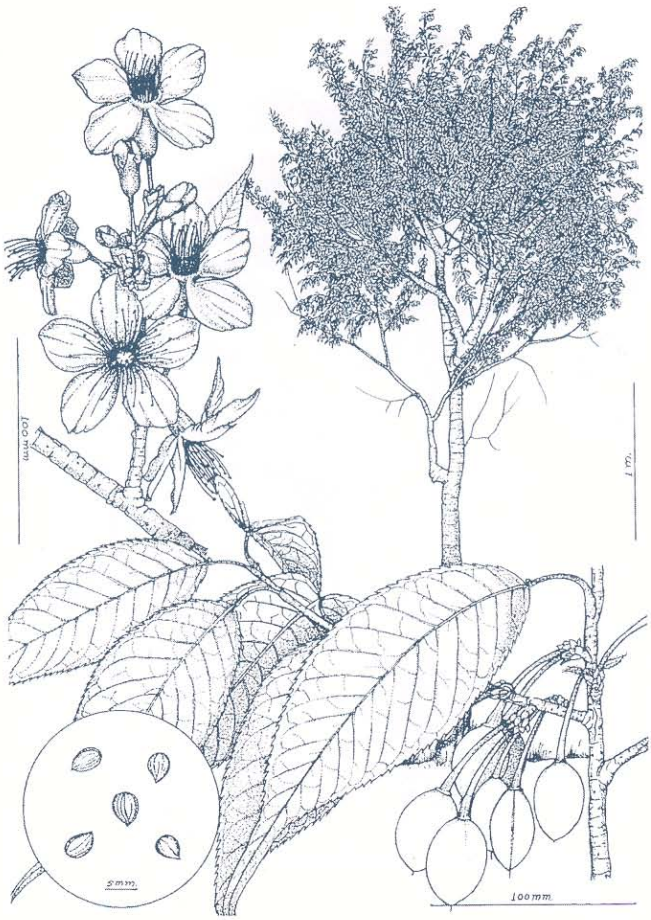
Cultivation and maintenance
Depending on the site, lankuri may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Lankuri can be lopped, and once the tree is established, thinning can be achieved by coppicing or pollarding.

Uses (other than bio-engineering)
Timber, fodder.





PAINYU

Prunus cerasoides
Cherry

Character
Medium-sized flowering tree.

Role in bio-engineering
Large tree planting.

Description
A medium-sized fodder tree. The leaves are pointed, have serrated edges and grow densely on the stems. When young, the stems have a bluish colour, but become pink with shiny bark when older, with white spots left from the leaf buds. The outer skin of the bark tends to peel off naturally.

Sites
500 – 2400 m
Painyu is very tolerant of poor soil conditions; in fact, it is the most tolerant broadleaf tree in the middle hills, growing on stony and sandy materials in sites drier than utis can tolerate. Young trees will grow under moderate shade, and so it can be grown under pioneer plantations of pines and utis, eventually replacing them as the long-term species.

Propagation
Propagation is by polypot seedlings raised from seed in a nursery. There are 2,500 seeds per kg, collected between Aswin and Mangsir (October to November). They remain viable for about 9 months.

Cultivation and maintenance
Depending on the site, painyu may require the following:

- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Painyu can be lopped, and once the tree is established, thinning can be achieved by coppicing or pollarding.

Uses (other than bio-engineering)
Firewood, fodder, timber.

PHALEDO

Erythrina species

Character

Three large fodder species.

Role in bio-engineering

Large hardwood cuttings (truncheon cuttings) are used as part of live check dams.

Description

A genus of large fodder trees. When young, there are thick thorns on the branches, but these disappear as the tree gets older. The flowers are a brilliant red. The leaves are broad, usually in a group of three.

Sites

900 – 3000 m

Phaledo tolerates a wide range of sites, but should not be planted in dry locations. Good growth can only be expected in reasonably moist sites with soil that is not too stony.

Propagation

For bio-engineering purposes it is normally propagated as a large hardwood cutting or truncheon cutting: these are typically 2 metres in length. The tree can also be grown from small cuttings (ideally 150 mm long and as thick as a pencil), but these would normally need to be grown on in a nursery. It can also be propagated from seed and raised in polypots in the nursery. There are 2,000 seeds per kg and they are collected between Mangsir and Falgun (November to March). They remain viable for about 5 years.

Cultivation and maintenance

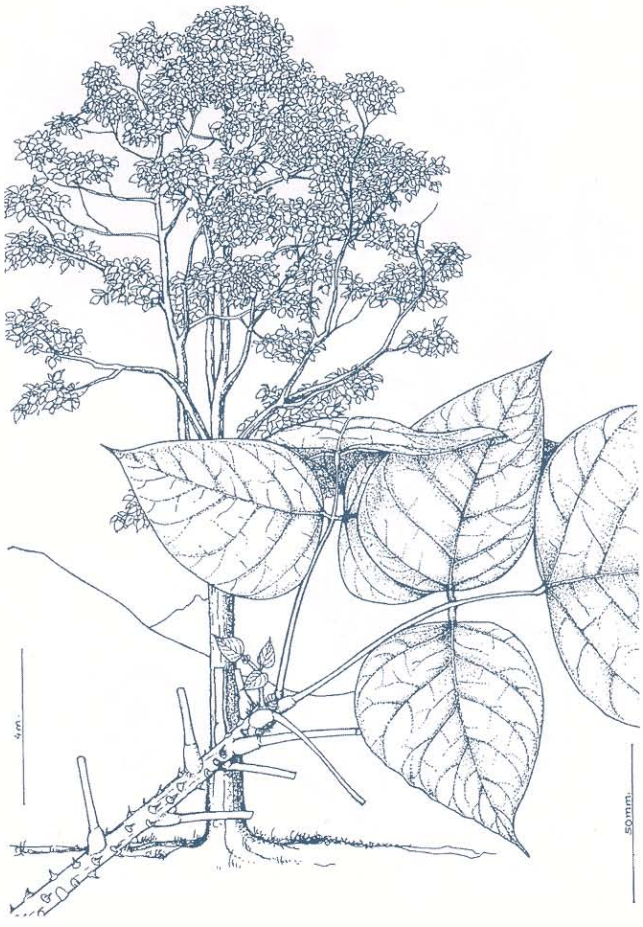
Depending on the site, phaledo may require the following:

- weeding;
- protection from grazing.

Thinning should be carried out when the plantation gets too dense. Phaledo can be lopped heavily, and thinning can be achieved by full coppicing or pollarding.

Uses (other than bio-engineering)

Fodder.

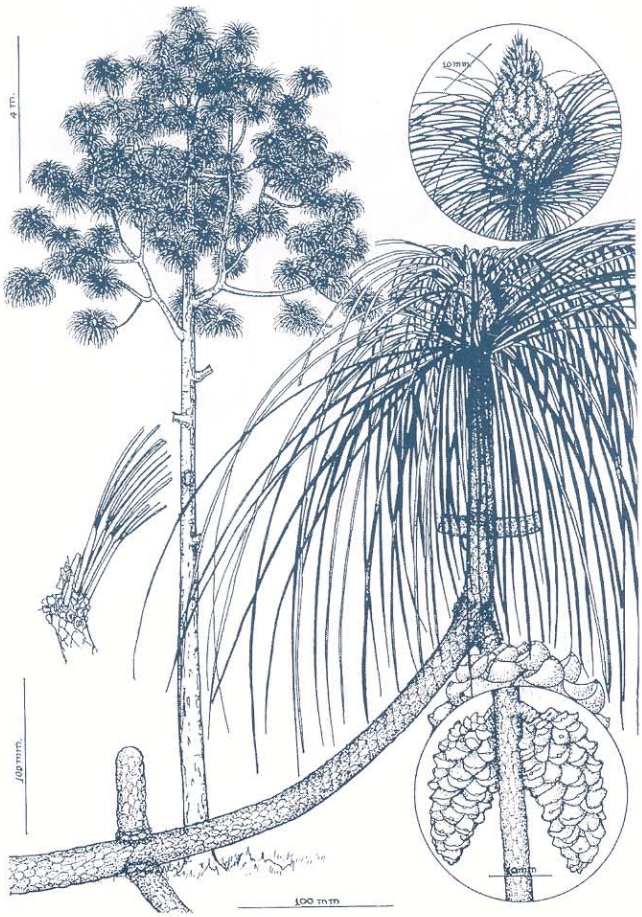


RANI (KHOTE) SALLA

Pinus roxburghii
Chir pine

Character
Large coniferous tree.

Role in bio-engineering
Large tree planting. Can also be sown directly on site (direct seeding or broadcasting).



Description
A large-stature tree, usually with a very straight trunk. Needles are long (about 300 mm) and characteristically occur in clusters of three. Below about 1800 metres, it is the only pine except in areas of old soil-conservation planting (where introduced pines are sometimes found).

Sites
500 – 1950 m
The indigenous low-altitude pine. Rani salla grows naturally on sites that are ecologically or climatically dry, and therefore is an indicator of rain shadow areas and other dry locations. Like most pines, it is a pioneer species and needs full light to grow. It is tolerant of exposed south-facing slopes, hot, dry sites and poor, stony soils. However, it does not grow down to the Terai and unlike khayer it performs badly on poorly drained materials.

Propagation
Propagation is by polypot seedlings raised from seed in a nursery. There are 8,000 seeds per kg, collected between Magh and Falgun (January to March). They remain viable for about 12 months.

Cultivation and maintenance
Depending on the site, rani salla may require the following:

- weeding (in the first two or three growing seasons: dense grass around the trunk is particularly harmful);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Small branches can be lopped, but pine trees should not be coppiced or pollarded.
Since rani salla is a pioneer species, it should not be grown as the main species on a site for more than about five years. Vegetation enrichment should be used to grow up other species between the pine trees, with the aim of changing the mixture and removing all pines by 10 years after the first planting.

Uses (other than bio-engineering)
Timber, firewood.

RATO SIRIS

Albizia julibrissin

Character

Medium-sized deciduous tree.

Role in bio-engineering

Large tree planting.

Description

A large tree, usually with a straight stem. The leaves are feathery in appearance;, they take a herringbone form, being small and thin, and growing opposite each other along the branches. The young leaves are red and, at this stage, are poisonous.

Sites

500 – 2500 m

Rato siris is the best of the siris trees on poor sites, and sometimes colonises landslides naturally. Like most trees, it prefers a fertile, loamy soil; but it can grow relatively quickly on poor, stony sites. It seems to have a low drought tolerance and naturally it occurs mainly in moist locations, such as near streams. Like utis, rato siris should, therefore, be planted in wetter sites.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 24,000 seeds per kg, collected between Aswin and Magh (September to February). They remain viable for about 5 years.

Cultivation and maintenance

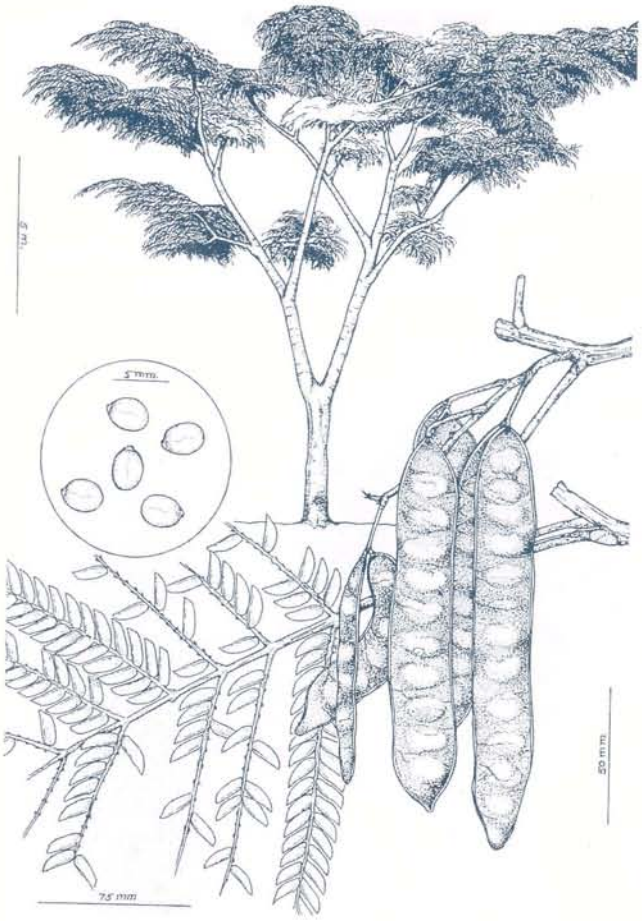
Depending on the site, rato siris may require the following:

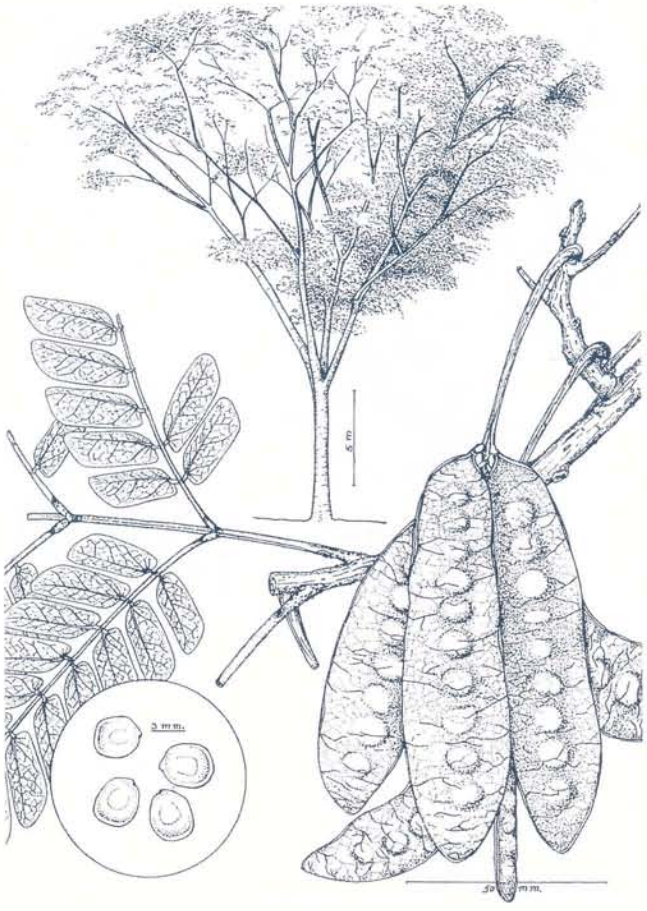
- weeding (in the first growing season only);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Rato siris can be lopped, and once the tree is established, thinning can be achieved by coppicing or pollarding.

Uses (other than bio-engineering)

Timber, fodder.





SETO SIRIS

Albizia procera

Character

Medium-sized deciduous tree.

Role in bio-engineering

Large tree planting.

Description

This tree has branches that are brittle and give off a strong smell when broken. Leaves are of a medium size and grow opposite each other in pairs. The stems are covered in brown spots. The seeds hang down in distinctive pods, 100 to 150 mm long.

Sites

Terai – 1350 m

A tree that grows best in damp and even waterlogged conditions, such as poorly drained clays. It grows poorly in dry sites. It prefers full light, but seedlings can tolerate some shade.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 18,000 seeds per kg, collected between Poush and Jestha (December to June). They remain viable for about 5 years.

Cultivation and maintenance

Depending on the site, seto siris may require the following:

- weeding (in the first two growing seasons, as grass competition is bad for seedlings);
- protection from grazing (until it grows out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Seto siris can be lopped, and once the tree is established, thinning can be achieved by coppicing or pollarding.

Uses (other than bio-engineering)

Firewood, timber, fodder.

SISAU

Dalbergia sissoo
Sissoo (a type of rosewood)

Character
Large broad-leaved tree.

Role in bio-engineering
Large tree planting. Can also be sown directly on site (direct seeding or broadcasting).

Description
The common low-altitude plantation tree. It is a full-stature tree with a slender, rarely straight stem. Leaves are round, but with a slight point, and generally less than 50 mm long.

Sites
Terai – 1400 m
One of the most versatile low-altitude trees. It occurs naturally in riverine sites, and so is tolerant both of long droughts on stony and gravelly materials, and of waterlogging and flooding. It grows slowly on very dry sites, but rarely dies completely. In fact, its rapid growth depends entirely on it being planted on a well drained, fertile soil with access to a reliable water table. But sisau is so robust that it will grow almost anywhere in its altitudinal range, even if very slowly. For bio-engineering purposes, it should not be planted on very hot, dry sites, where khayer performs better.

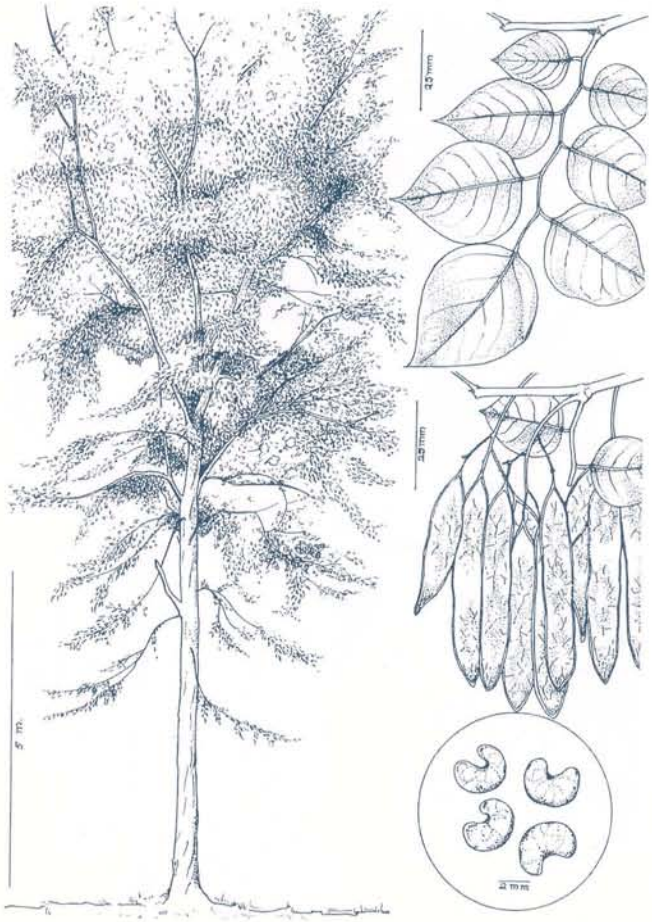
Propagation
Propagation is by polypot seedlings raised from seed in a nursery. There are 33,000 seeds per kg, collected between Falgun and Baisakh (February to May). They remain viable for about 12 months.

Cultivation and maintenance
Depending on the site, sisau may require the following:

- weeding (in the first growing seasons only);
- protection from grazing (until it grows out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Sisau can be lopped, and once the tree is established, thinning can be achieved by coppicing or pollarding.

Uses (other than bio-engineering)
Timber, firewood, fodder.



UTIS

Alnus nepalensis
Nepalese alder

Character

Large broad-leaved tree.

Role in bio-engineering

Large tree planting. Can also be sown directly on site (broadcasting only).

Description

A large-stature tree with a straight stem. Leaves are usually dark green in colour, rounded at the sides but with a point. They are about 50 mm wide and 80 mm long. Groups of utis trees usually have noisy insect colonies and the leaves are often full of holes from insect attacks.

Sites

900 – 2700 m

Utis is a well known natural coloniser of landslides and gullies in the middle hills. It needs damp or shady conditions, but then will tolerate the poorest and stoniest of materials. Soils should be permeable rather than hard or massive. Although it grows best in damp locations, it avoids waterlogged areas.

Propagation

Propagation is by polypot seedlings raised from seed in a nursery. There are 500,000 seeds per kg, collected between Mangsir and Falgun (November to March). They remain viable for about 18 months.

Cultivation and maintenance

Depending on the site, utis may require the following:

- weeding (in the first two or three growing seasons: dense grass around the trunk impedes growth significantly);
- protection from grazing (until it gets out of the reach of animals).

Thinning should be carried out when the plantation gets too dense. Branches can be lopped, but utis trees should not be coppiced or pollarded except in very good growing sites.

Since utis is a pioneer species, it should not be grown as the main species on a site for more than about five years. Vegetation enrichment should be used to grow up other species between the utis trees, with the aim of changing the mixture and removing all utis by 10 years after the first planting.

Uses (other than bio-engineering)
Firewood, timber, fodder.

LARGE CLUMPING BAMBOOS

CHOYA/TAMA BANS

Dendrocalamus hamiltonii

Character
Large clumping bamboo.

Role in bio-engineering
Large bamboo planting.

Description
A large-stature bamboo with larger leaves than most other species. It has thin culms and heavy branching. The culm splits easily between the nodes, to give soft, flexible sections.

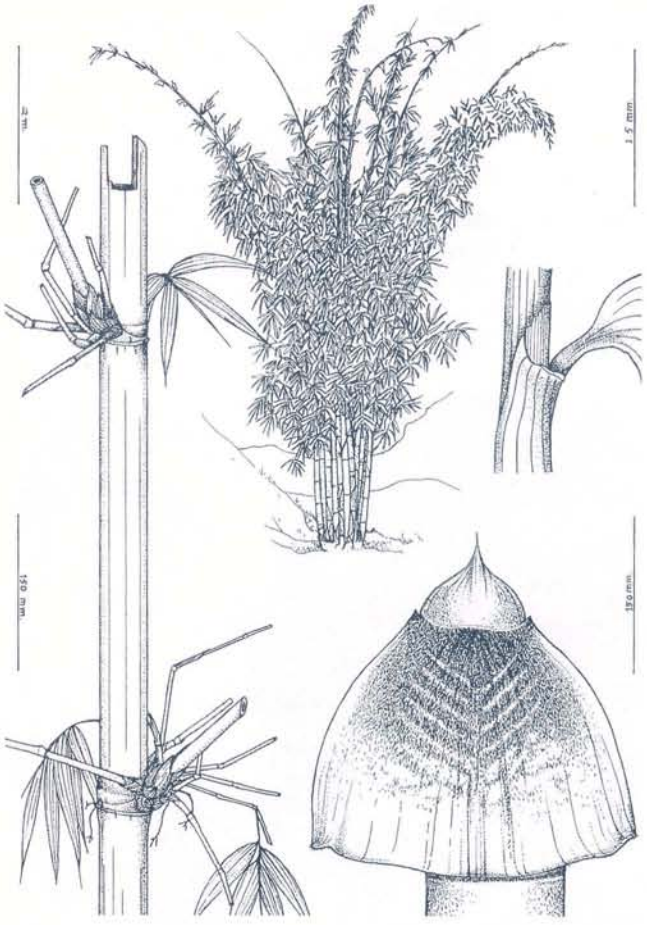
Sites
300 – 2000 m
This is the most widely cultivated of all the bamboos. As with all large bamboos, it grows best in moist, shady sites. It should not be planted on south-facing slopes below 1200 metres. Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

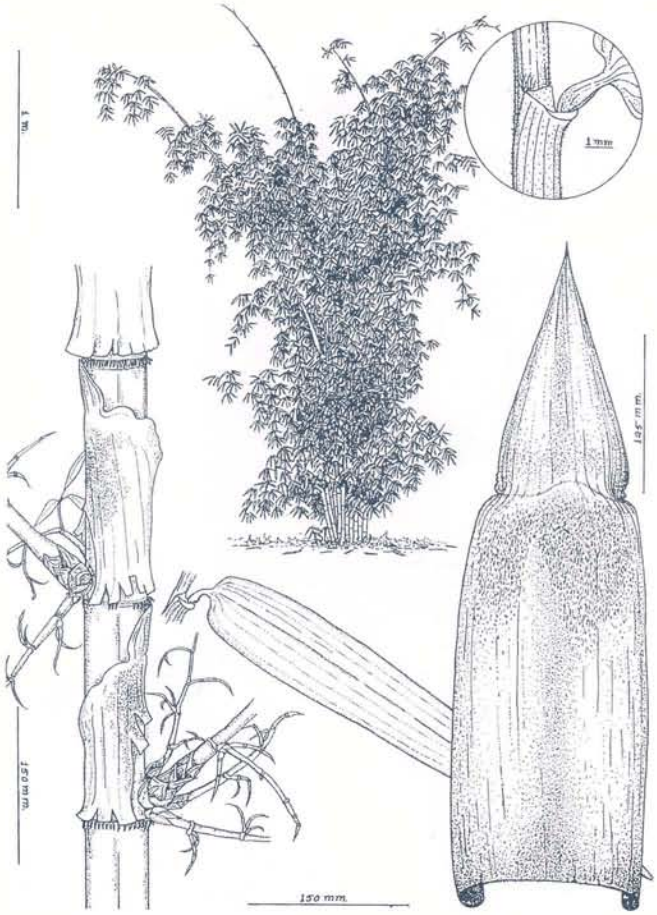
Propagation
Choya bans is the easiest of the large bamboos to propagate. It has heavy branching from the nodes, and so can be propagated from single node culm cuttings raised in a nursery. It can also be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long. It flowers relatively often for a bamboo, and so seeds can be obtained quite often. They are viable for at least one year.

Cultivation and maintenance
Depending on the site, choya bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Uses (other than bio-engineering)
Weaving, fodder, edible shoots.





DHANU BANS

Bambusa balcooa

Character

Large clumping bamboo with a thin culm and heavy branching.

Role in bio-engineering

Large bamboo planting.

Description

A very large-stature bamboo with characteristically bowed culms. Branching is heavy and, lower down, fairly thorny. The culms are often topless, since they are very brittle when young and can be broken by the weight of a bird.

Sites

Terai – 1600 m

Grows on south-facing sites between 1400 and 1800 metres. Dhanu bans tolerates dry conditions better than any of the other large bamboos, but it still grows much better in shady gullies than on dry slopes. Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

Propagation

Dhanu bans is one of the easier of the large bamboos to propagate. It has heavy branching from the nodes, and so can be propagated from single-node culm cuttings raised in a nursery. It can also be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long.

Cultivation and maintenance

Depending on the site, dhanu bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Uses (other than bio-engineering)

House construction (poles, *etc.*) and scaffolding.

KALO BANS

Dendrocalamus hookeri

Character

Large clumping bamboo with heavy branching, brown hairs.

Role in bio-engineering

Large bamboo planting.

Description

Very similar in appearance to dhanu bans, but with thinner culm walls and no low branching. Culms and culm sheaths are often covered in brown hairs, and are dark green to black in colour. This species tends to flower more quickly than other species of bamboo, although this is still quite rare.

Sites

1200 – 2500 m

A bamboo commonly cultivated in eastern Nepal. It is the most frost resistant of the large bamboos, and so can be used to the highest extent of the main road network. It grows best in cool, shady gullies and on north-facing slopes. Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

Propagation

Kalo bans is one of the easier of the large bamboos to propagate. It has heavy branching from the nodes, and so can be propagated from single node culm cuttings raised in a nursery. It can also be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long. Seeds are available in most years and so plants can be raised as polypot seedlings in a nursery as well.

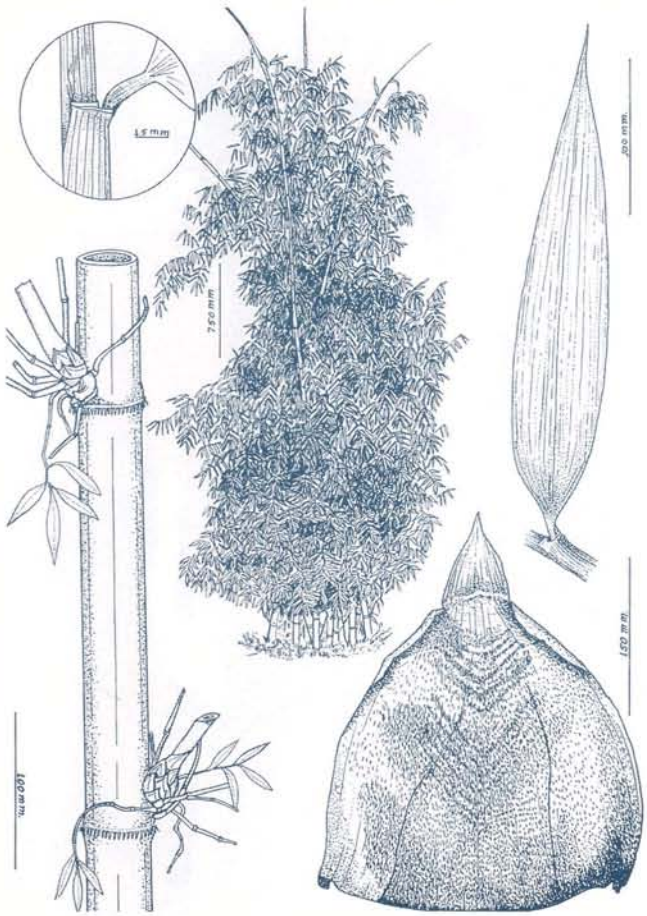
Cultivation and maintenance

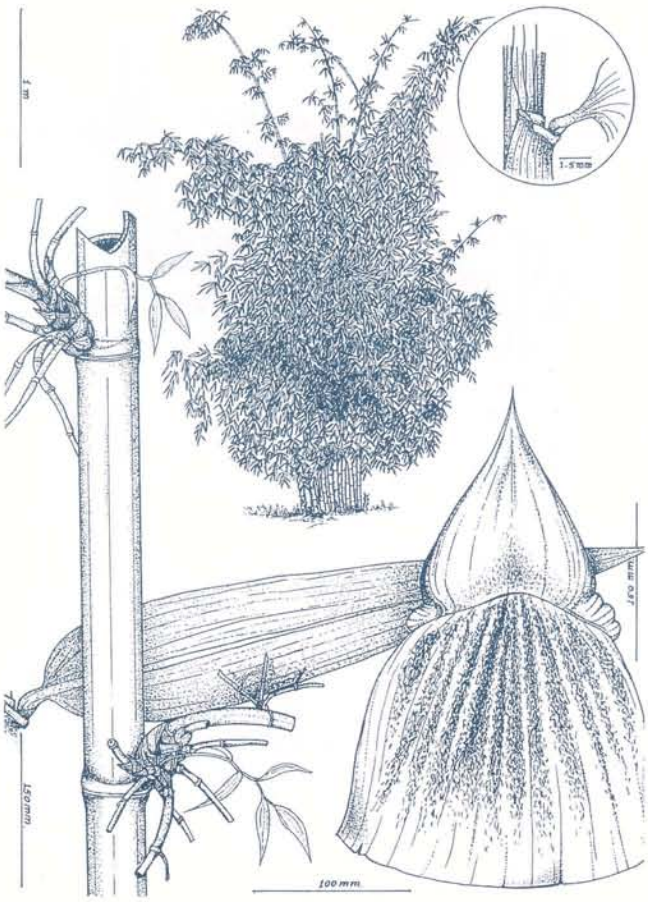
Depending on the site, kalo bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Uses (other than bio-engineering)

Construction, fodder.





MAL BANS

Bambusa nutans subspecies *cupulata*

Character

Large clumping bamboo with strong, straight culms.

Role in bio-engineering

Large bamboo planting.

Description

A large-stature bamboo with round, straight culms. The distance between the nodes is greater than for almost all other bamboos. The culms have many small branches from almost every node. The culms are used very widely for construction.

Sites

Terai – 1500 m

Mal bans is relatively tolerant of dry conditions for a bamboo, but as with all the large bamboos, grows best in damper sites and gullies. Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

Propagation

Mal bans should be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long.

Cultivation and maintenance

Depending on the site, mal bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Uses (other than bio-engineering)

Construction, fodder.

NIBHA/GHOPI/LYAS BANS

Ampelocalamus patellaris

Character

Large clumping bamboo with smaller, bluish culms.

Role in bio-engineering

Large bamboo planting.

Description

A small stature bamboo with culms that are nearly blue. The culms are usually less than 20 mm in diameter. Nodes have a woody ring immediately below them. If the culm is more than 2 years old, roots and heavy branches emerge from the nodes. In the wettest sites, clumps grow to a diameter of 2.5 metres.

Sites

1200 – 2000 m

This species tends to grow only in very wet sites. It is most common in the higher rainfall areas (such as Ilam and Taplejung, and Kaski and Palpa). Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

Propagation

Nibha bans should be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long. If aerial roots have formed from a node, it should be possible to propagate it from single-node culm cuttings raised in a nursery.

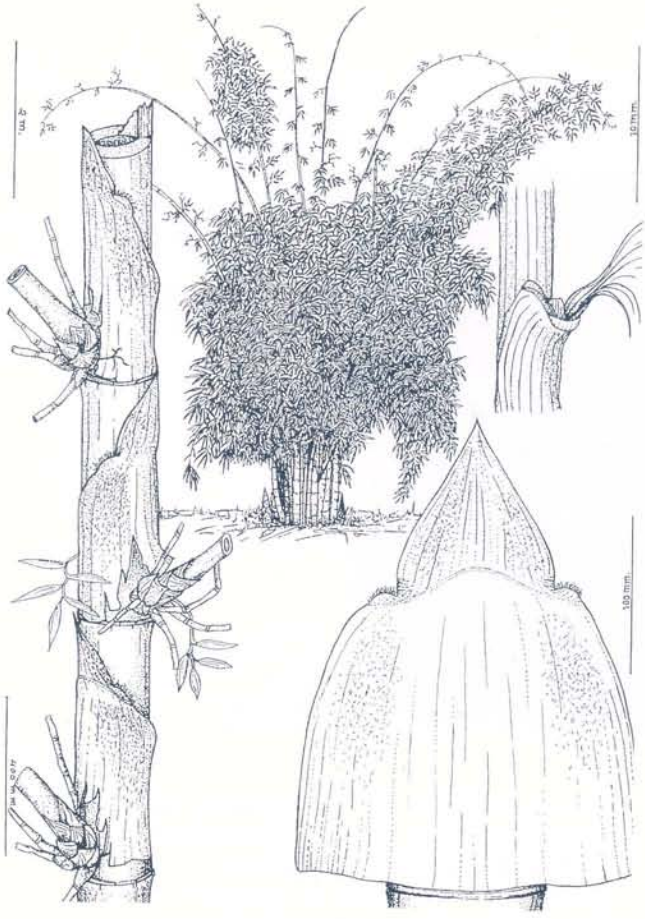
Cultivation and maintenance

Depending on the site, nibha bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Uses (other than bio-engineering)

Weaving, fodder.



THARU BANS

Bambusa nutans subspecies *nutans*

Character

Large clumping bamboo with strong, straight culms.

Role in bio-engineering

Large bamboo planting.

Description

The central Nepal equivalent to mal bans and very similar in appearance, having round, straight culms and many branches from the nodes. Branching is stronger than mal bans; the clumps are denser and the culms have minor differences.

Sites

Terai – 1500 m

Tharu bans is relatively tolerant of dry conditions for a bamboo, but as with all the large bamboos, grows best in damper sites and gullies. Survival is much better on permeable materials and in debris and fill sites than on cut slopes and hard original ground.

Propagation

Tharu bans should be planted directly on site using the traditional method of a large section of rhizome and culm about 2 metres long.

Cultivation and maintenance

Depending on the site, tharu bans may require the following:

- watering (in the first season only, before the monsoon rains start);
- mulching and weeding (in the first two or three growing seasons);
- protection from grazing (until large shoots have grown out of the reach of animals).

Tharu bans can lose most of its leaves in the spring drought, without any harm.

Uses (other than bio-engineering)

Construction, lych poles, rough weaving.