“Plantations are a major source of industrial wood in Africa. Many projects, however, have performed poorly because of poor species choice, lack of species trials, limited site characterisation and unforeseen pests”

(from: The Regional Impacts of Climate Change. UNEP/WMO Intergovernmental Panel on Climate Change, 2005).

A mature Musizi (Maesopsis eminii) tree in Budongo Forest. Musizi is a fast growing indigenous hard wood.

Eucalyptus grandis grown for sawtimber in South Africa. This stand is 15 years old and has well thinned.

(left) 3-yr old plantation of Pinus caribaea var. hondurensis in Nakasongola: seed from clonal seed orchards in Queensland, Australia. This is one of a number of demonstration blocks around Uganda planted in 2002-03 to encourage private investors.
So...you are interested in planting trees commercially in Uganda are you? Well the most important decision you have to make is what species to plant. This depends primarily on two main things: firstly - what products you want to produce and secondly what species will grow well on your land. This Guideline will aid this decision with details of the silviculture and management of potential species, as well as their growth rates, expected rotations and the wood’s utilisation characteristics.

Before planting any particular tree species (especially on a commercial scale), it is essential to understand their site requirements and their growth characteristics. Failure to appreciate this will often result in a crop that does not perform well and may well result in the plantation development being a financial disaster.

It should be noted that the species referred to in this Guideline are only those with potential for commercial scale sawlog (i.e. timber) production. Of course, many of the species will produce other products as well (such as fuelwood and poles) but still the main aim of the National Forest Authority (NFA) and private investors - especially those on the Sawlog Production Grant Scheme (SPGS) - is timber production. NB. The centre 4 pages of this guideline give details of matching the main species to sites in Uganda.

EXOTIC VS INDIGENOUS

We are often asked why most of the species recommended for commercial plantations are exotic (i.e. not native to Uganda) and why we don’t plant more indigenous species. The main reason is that most of the indigenous trees grow too slowly (e.g. Mahoganies (Khaya anthothica and Entandrophragma spp.) and Mvule (Milicia excelsa) and thus render the investment unprofitable. Many indigenous species are also very difficult to grow in a plantation situation (e.g. Mvule and Prunus africanaum). The exception to this is Musizi (Maesopsis eminii), which is a fast growing indigenous tree with considerable promise for timber plantations on suitable sites in Uganda. On appropriate sites, however, we do encourage planters to plant a proportion of indigenous trees but for commercial reasons, faster growing trees - especially Eucalypts and Pines - will dominate plantations for timber in Uganda for the foreseeable future.

Pines and Eucalypts are the main species used for plantations throughout the tropics and sub-tropics because of their ability to grow well in a plantation situation. They are natural pioneer species – which means they are adapted to grow over a range of sites and in an open situation. In addition, there is a lot known about their silviculture – both in the nursery and in the field situation – and also their growth and utilisation characteristics. Breeding programmes in a number of countries also means that there is improved seed available for the most important commercial species.

MIXED SPECIES OR MONOCULTURE? EVEN OR UNEVEN AGED?

The vast majority of commercial plantations worldwide are monocultures i.e. comprising one species only in a given area. Additionally, each block (usually called compartment or sub compartment) will be of the exact same age. Conservationists often criticise commercial forestry organisations for this approach but they fail to understand the economics of plantation forestry and also the complexities of managing different species and/or ages growing together. A sound plantation development, however, should develop a mosaic of different species and ages over the estate. With fast growing Eucalypts on specific sites, it is also recommended to apply fertiliser to maintain the nutrient status of the soil.

The main plantation species referred to in this guideline – especially Pines and Eucalypts – can produce very high yields when grown intensively in a monoculture, even-aged situation. Silvicultural prescriptions (and budget figures) can also then be easily applied to large areas. There are huge economies of scale to be made having blocks of trees the same species and age/size.

RISKS

Growing large blocks of monocultures (and with a narrow genetic base if using improved seed) comes at a price too. Such plantations are more at risk than a natural population when it comes to fires and pests and diseases and hence, precautions have to be taken to minimise such risks – e.g. restricting compartments to maximum 30ha; having blocks of different ages and species scattered throughout the estate; developing infrastructure (especially roads); having a fire prevention and control plan.
An important – though longer term - method of reducing risk is to have in place a breeding programme that maintains a wide genetic base that could be called on should there be a catastrophic pest or disease outbreak in any of the major species in the plantation programme.

BE SCIENTIFIC!

Going to a nursery and asking for Pine or Eucalypt seedlings is like going to a library and just asking for a book: you are highly unlikely to get the one you wanted! There are over 100 different species of Pine and some 600 Eucalypt species - each with their own characteristics. For commercial plantations, it is essential to select not just the correct species for the site but to obtain the right seed origin or provenance from within a particular species. Thus the recommendations in this Guideline are very specific and should be carefully followed.

SPECIES IN THIS GUIDELINE

We considered a long list of potential plantation species for inclusion in this Guideline. The species were split into two categories - primary and secondary. Only the former group of species have been included here: the secondary group will feature in Plantation Guideline No. 13. The primary group are those species which are currently being planted for commercial timber production in Uganda. Please bear in mind, however, the comments made earlier in the Introduction section about matching sites with species. The secondary group is a mixed group of species that fit into one of the following categories: those only likely to be useful on a very limited area in Uganda, those severely limited by seed availability or those worthy of trial before recommending wider planting here.

SPECIES LIST ( * = indigenous to Uganda)

PRIMARY:  *Eucalyptus grandis, Pinus caribaea var. hondurensis, Maesopsis eminii*, Pinus patula, Pinus oocarpa, Cupressus lusitanica, Araucaria cunninghamii, Tectona grandis, Terminalia suberba.

SECONDARY:  Araucaria hunsteinii, Terminalia ivorenensis, Pinus kesiya, P. tecunumanii, Eucalyptus camaldulensis, E. tereticornis, E. pilularis, E. urophylla, E. paniculata, hybrid Eucalyptus clones (GU & GC), Cedrela odorata, Agathis robusta, Prunus africanaum*, Podocarpus spp*, Grevillea robusta, Mahoganies* (Khaya anthotheca, Entandrophragma spp); Milicia excelsa*.

ABBREVIATIONS

In the interest of space in the species’ datasheets, standard abbreviations have been used:

asl  above sea level (in metres)
ERD  effective rooting depth (cm)
ha  hectares (1ha = 2.47 acres)
Lat.   Latitude
Long.   Longitude
MAI  mean annual increment (m³/ha/yr).
MAR  mean annual rainfall (mm)
spf  stems per hectare

SOURCES OF INFORMATION:

Birks JS & RD Barnes, 1990.  


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Forestry Compendium (CD-ROM).

Eldridge K et al, 1993.  

Plantation Forestry in the Tropics (3rd edn.). Oxford University Press.

Silviculture in the Tropics. GTZ Publications.

UNASILVA (special edn. on Teak) No. 201, 2000.  
Available free on www.fao.org
EUCALYPTUS GRANDIS

Family: Myrtaceae
Common names: Blue gum; Saligna; "Kalitunsi"

Natural Occurrence
EG occurs naturally in Australia between Lat. 16°S (N. Queensland) and 33°S (NSW), mostly in coastal areas and up to 600m asl. EG grows to 75m in places.

History of Growing in Plantations
EG is one of main sub-tropical/tropical plantation species worldwide, with well over 2M ha planted (mainly Brazil, India, Southern & Eastern Africa). Grown in Ug since 1912 but species has hybridised and very few pure EG now. Well known to Ug farmers and is a common cash crop for fuel and poles. Grown commercially as a fuelwood crop in tea estates throughout Ug.

Characteristics & Uses
EG has very versatile wood properties including excellent pulp and paper qualities. In Ug it is frequently grown for fuelwood, building poles and is increasingly used as a source of timber, large poles and veneer. The sapwood is pale pink; the heartwood darkens to a richer red-brown on exposure to the light. It has an air-dry density of 600-750kgs/m³. EG wood is not naturally durable and thus must be treated if in contact with the ground. Fast grown trees can have growth stresses and appropriate utilization techniques must be used to achieve good recovery rates. EG is an excellent source of nectar for bees.

Site Requirements:
ERD: at least 750 mm with no impediment to rooting (any stone-lines must be shattered before planting). MAR: requires >1,000mm/yr. Alt. EG prefers cooler climates (in Ug, best growth is in western region). EG does not tolerate severe droughts; it is tolerant of waterlogging but for a short time only.

Seed Recommendations
For commercial plantations, use only improved seed from seed orchards in Southern Africa. Best local stand is Fort Portal; other locally collected seed is highly likely to be contaminated (hybridised) and will not perform as well. Hybrid clones (with EG as mother) are planted more than pure EG worldwide now but are still in the research phase in Ug.

Summary:
On good sites EG can grow extremely quickly but it requires good land preparation and thorough weeding. EG can produce timber and large poles in only 8-15 years but only if thinned early and heavily. It is also essential to use only improved, select seed. Easy to raise from seed and coppices vigorously.

Silviculture:
Seedlings: mature in 3 months in nursery from seed. Spacing: for fuelwood and small poles: 2.5 x 2.5m to 2.0 x 2.0m (1600-2500 sph); for timber and big poles: 3.0 x 3.0m to 2.7 x 2.7m (1111-1372 sph). Establishment: EG is very sensitive to competition (especially grasses) early on in its life and thus sites must be kept weed free until canopy closure for maximum yields. Pre-plant spraying with Glyphosate is the most cost-effective method of weed control. EG responds well to fertiliser at planting too. Management: EG is a light demanding, shade intolerant species, which responds well to thinning. To produce large diameter stems for timber and poles, EG must be thinned heavily from an early age - starting no later than 2 years in Ug. Final crop densities of 250-400 sph are recommended. EG plantations do not respond to thinning or weeding once they have stagnated due to either weed competition or dense stocking. Pruning in stages will also be necessary to produce high quality sawlogs.

Yields:
On suitable sites and with good silviculture EG can produce outstanding growth - MAIs >50m³/ha/yr have been achieved in western Ug. Avg. MAIs expected in Uganda are 25-45m³/ha/yr. With poor silviculture, EG will grow slowly and can totally fail. Rotations for sawlogs expected to be 8-15 years.

Common Pests & Diseases:
Good silviculture (i.e. minimum stress) will greatly reduce EG’s susceptibility to the Chalcid wasp in Ug. Termites are a major problem in hot, dry areas - but these are not good EG sites anyway. Prone to range stem canker diseases, hence the use of clonal hybrids.

Other Issues:
Complaints of excessive water use are periodically blamed on EG. Rapidly grown plantations of any intensively grown crop may reduce water catchment yields - thus care must be taken when selecting sites for large-scale EG planting.
**PINUS CARIBEA VAR. HONDURENSIS**

*Family:* Pinaceae  
*Common names:* Caribbean pine; Pitch pine.

**Natural Occurrence**  
PCH has a wide natural distribution in the Caribbean basin from lat. 12°-27°N; long. 77°-90°W; mostly at low elevations up to 760m asl. PCH varies much in form and growth throughout its natural range.

**History of Growing in Plantations**  
PCH is planted widely for its timber throughout the American, Asian and African tropics and sub-tropics. In Ug it was introduced in the 1960’s but not from the best seed sources. Many of the best individuals have since been felled.

**Characteristics & Uses**  
PCH is a fast growing and versatile tree for tropical lowland plantations. Its needles usually occur in fascicles of 3. PCH generally forms a straight stem - up to 45m under favourable conditions. It produces a versatile wood (density 400-650kg/m³) which saws, dries and machines easily. Trees >12 years can develop resin in the heartwood - heavy pruning helps reduce this. PCH can produce good quality oleoresin which can be distilled to produce terpentine and other products.

**Site Requirements:**  
PCH grows on a wide range of tropical and sub-tropical sites at altitudes up to 1500m asl (usually <1000m). PCH requires an ERD of at least 600mm and shallow sites should be avoided. It is moderately drought resistant. MAR: requires >1000mm/yr.

**Seed Recommendations**  
Natural populations of PCH exhibit great variation in growth rate, stem form and branch characteristics. PCH has been the focus of international provenance (seed origin) trials since the 1970’s. Results have proven that the Australian clonal seed orchard seed (from Forest Plantations Queensland, Australia) has consistently performed better than natural collections. Improved seed from South African (Mondi) and Brazilian seed stands is also recommended for Ug.

**Silviculture:**  
**Seedlings:** PCH is easy to raise from seed: mature in 4 months in nursery from seed. Mycorrhiza are needed for seedling growth: thus litter from old stands must be added to nursery potting mix.  
**Spacing:** 3.0 x 3.0m (1111 sph) recommended for timber stands being raised from improved seed.

**Establishment:** PCH requires full sunlight to grow - thus the site must be cleared well before planting. Whilst PCH can tolerate some weed competition, it cannot tolerate overhead shade. For best growth, keep the 1m diameter planting pits clear of weeds and slash the interrow vegetation frequently until canopy closure. On very weedy sites, pre-plant spraying with Glyphosate will be cost-effective.

**Management:** To produce large diameter stems quickly, PCH must be heavily thinned. The actual age of thinnings will depend on growth rates but on average in Ug, 1st thin @ 4-6yrs to ca.722 sph (35%); 2nd thin @ 8-10yrs to ca.469 sph (35%); 3rd thin @ 12-14yrs (35%) to a final crop of ca.300 sph. High pruning in stages is recommended to produce clean logs. Because of PCH’s light canopy, stands will have to be periodically cleaned to keep weed growth in check. PCH is moderately fire resistant after ca. 5 yrs when it develops thicker bark.

**Yields:**  
PCH can produce MAIs of > 30 m³/ha/yr on good sites in Ug but only with excellent silviculture. Avg. MAIs expected are 15-25m³/ha/yr. Rotations for sawlogs are expected to be 18-25 years.

**Common Pests & Diseases:**  
PCH is susceptible to damping off in the nursery. It is also prone to root rot fungi (e.g. *Armillaria mellea*, *Phytophthora cinnamomi*) in young plantations, which can cause isolated (or group) deaths. Susceptible in some countries to fungal needle diseases (e.g. *Mycosphaerella* spp.) in young plants.

**Other Issues:**  
The availability of improved seed has restricted planting of PCH in some countries (including Ug in 2005) though efforts to increase imports are underway. Foxtailing can be significant if grown on very fertile sites: rather plant hardwoods.

**SUMMARY:**  
PCH is a fast growing tropical species that adapts to a wide range of sites. It is the prime species for timber plantations in Ug - especially for the shallower soils on lower elevation sites. Only imported, improved seed is recommended for commercial planting in Ug.
MAESOPSIS EMINII

Family: Rhamnaceae
Common names: Musizi.

Natural Occurrence
MUS occurs between 8°N and 6°S in a band across West, Central and East Africa from Kenya to Liberia. MUS is found throughout the wetter parts of Ug, being a coloniser of disturbed forest.

History of Growing in Plantations
MUS has been used more for enrichment planting in NHF than pure plantations in Ug. Many of these trees (from the 1960’s and ‘70s) have since disappeared from the CFRe where they were planted, being targetted by timber thieves. Farmers in Ug do, however, frequently plant MUS as shade for crops (including coffee and cocoa) and also value its timber. The potential of MUS has long been recognised and it is now being promoted for timber plantations on suitable (fertile) sites around Ug.

Characteristics & Uses
MUS is a semi-deciduous tree that produces a widely used, general purpose timber (380-480kg/m³). The wood is light brown and easily saws, dries and machines, though it has inter-locked grain and thus doesn’t finish well. It is used mostly for general indoor construction. MUS is not liked for exterior work (or veneers) because its yellow heartwood stains paint.

Site Requirements:
MUS requires moderately fertile, deep and well-drained soils. It needs MAR of >1200mm (but does tolerate some drought) and altitudes <1200m asl.

Seed Recommendations
Since MUS has not been acknowledged as a major commercial plantation species, there is no genetically improved seed available. Potential growers are thus recommended to use only seed from selected ‘plus trees’ (i.e. mother trees with superior characteristics). The NFA’s National Tree Seed Centre should have such seed available.

SUMMARY:
MUS is a fast growing indigenous tree of considerable promise for timber production in Ug. It is a natural colonising species and is widely used for enrichment planting and as shade for agricultural crops in Ug. Its stem moves towards the light and thus plantations must be thinned on time.

Silviculture:
Seedlings: plantable seedlings (ca. 20cm tall) should be ready 3-4 months after sowing. Germination can be erratic.

Spacing: For dedicated timber plantations, MUS should be grown at a spacing of 4 x 4m (625sph) or 3 x 3m (1111sph): the latter spacing will give better weed control and quicker canopy closure. For agroforestry situations (and where timber production is also an objective) a wider spacing can be employed e.g. 6 x 6m (277sph).

Establishment: MUS is a light demanding species and sensitive to competition. It must be well weeded and not over-shaded by weeds. Low agricultural crops (beans e.g.) can be grown between the tree rows provided the trees are not interfered with.

Management: MUS stands must be thinned early to ensure the crowns have unrestricted access to light. Typical thinning regime for a 3x3m spaced crop would be: remove 50% ca. yr 4; then a further 50% at yr 8; 50% yr. 12. Although naturally self-pruning in the NHF situation, MUS can develop large branches when grown in more open situations and thus pruning to produce clean lower stems is thus recommended. MUS is reported to coppice freely after being cut and is highly susceptible to fire.

Yields:
MUS has not been grown intensively in pure stands in Ug but yields are expected to be around 15-25m³/ha/yr. Rotations for sawlogs are expected to be 15-25 years but will depend largely on site conditions and management regime (especially espacement).

Common Pests & Diseases:
MUS trees are susceptible to browsing damage by wild antelopes after planting out. They can also develop stem cankers (Fusarium spp.) when stressed.

Other Issues:
MUS is considered an ‘invasive alien’ in the East Usambaras in Tanzania due to its aggressive colonising abilities. In Ug MUS offers a high potential for timber production in degraded forest land but more research is needed to determine the species’ best management practices.
INTRODUCTION

One of the most important decisions to be made by the potential investor in commercial tree planting is what species to plant on their land. The choice depends on a number of issues – including the availability of improved seed and the likely markets for the products. However, the most important question to consider first is - “what species will grow well on my particular site?”

Far too often growers in Uganda have decided on what they want to grow before considering the silvicultural requirements of the particular species and this can have disastrous consequences. For example, planting *E. grandis* in very hot areas of the country will cause it to be highly stressed and vulnerable to pests and diseases (and this is exacerbated by poor weeding). Also planting *P. patula* on low lying areas over most of Uganda, will result in a failed investment. Yes, the trees will often grow well for the first few years but then they will become stressed and start dying back. Why? Because *P. patula* needs a cool climate only found in the highlands of the West and South-West of Uganda. Teak (*Tectona grandis*) is also increasingly being planted all over Uganda and is struggling on most sites. Why? Because teak requires very specific climatic/site conditions – most notably, low altitude and a long dry season – conditions more readily found in southern Sudan and Tanzania.

SILVICULTURAL CLASSIFICATION MAP

In order to assist growers in Uganda, we have produced a map (Page 8) which provides a broad silvicultural classification of Uganda. This map was the result of some work commissioned just prior to the SPGS being launched in late 2003, when we hired the services of Pat Hardcastle from LTS International. It proved not an easy task due especially to the enormous loss of forest research data and also the lack of reliable meteorological data after the 1960’s. Against all odds, however, Pat used his experience of a similar exercise carried out in Malawi to come up with the map shown. We have also drawn sketch maps showing where the main species are roughly suited to in Uganda (Page 10). NB. All these maps are only approximate guides as to which species will grow where.

Successful commercial forestry plantations require that the tree species used are well adapted to the site. The aim of this work was to try and determine which species are best suited to what sites within Uganda. The recommendations given are based on current information and knowledge. It does not mean, of course, that species will not grow in other areas. The recommendations are to secure profitable growth. Details of the zones and the species suited to those zones are on Page 9.

METHODOLOGY

Tree species evolve in response to the conditions in their natural environment. The key factors are the availability of water and nutrients. Trees are also affected by temperature - some preferring cold area and others hot ones. Water availability depends primarily on total rainfall and its distribution. It also depends on the depth of soil and the texture. Clay soil holds more water than sandy soil.

In order to create the 10 zones shown on the map, information on the monthly rainfall at a range of stations was examined together with information on the loss of soil water from tree crops by transpiration. Information was also gathered on temperature. From models showing the balance between rainfall (water coming in) and transpiration (water going out) for some 25 locations in Uganda, a set of relatively similar climatic regions was defined. These are zones A to L (note there is no F or I as these letters can be easily misread).

Using historical knowledge from Uganda and countries with similar conditions, recommendations were made on what species should be planted in which zones. Soil factors must also be considered, not just fertility but also characteristics such as texture, waterlogging, stoniness and compaction as trees vary in their ability to cope with different soil characteristics. This knowledge must also be used in making the final species choice.

LIMITATIONS

It proved impossible to find good recent information on climate and so that used was taken from the National Atlas of Uganda (1967 - 2nd edn.). The mapping was done at a scale of 1:1 M and so it is impossible to expect it to show local details. The zonation is a guide that can be used to assist decision making.
MATCHING TREE SPECIES TO SITE

Silvicultural zones
- A - Cold, Wet - MAT < 18, RF > 1250 mm - Fair potential, little land available
- B - Cold, Dry - MAT < 18, RF < 1250 - Little potential
- C - Cool, Dry - MAT 18 - 22, RF 1250 - 1500 - Some potential, careful site analysis required
- D - Cool, Moist - MAT 18 - 22, RF 1250 - 1500 - Good potential
- E - Cool, Wet - MAT 18 - 22, RF > 1500 - Very high potential
- G - Warm, Wet - MAT 22 - 24, RF > 1250 - Very high potential
- H - Hot, Wet - MAT 23 - 24, RF > 1250 - High potential with careful practices
- J - Hot, Dry - MAT 22 - 24, RF 1000 - 1250 - Some potential with careful site analysis
- K - Very Hot, Wet - MAT > 24, RF > 1250 - Good potential, largely untested
- L - (Very) Hot and Very Dry - MAT > 22, RF < 1000 - No potential except on favourable microsites

Scale: 1:3,800,000

International boundary
Town
Road
Lake
<table>
<thead>
<tr>
<th>ZONENAME</th>
<th>MEAN ANNUAL TEMPERATURE</th>
<th>MEAN ANNUAL RAINFALL</th>
<th>POTENTIAL FOR COMMERCIAL PLANTATIONS</th>
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<tbody>
<tr>
<td>A</td>
<td>Cold, Wet</td>
<td>&lt;18°C</td>
<td>&gt; 1250 mm</td>
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<tr>
<td>B</td>
<td>Cold, Dry</td>
<td>&lt;18 °C</td>
<td>&lt; 1250 mm</td>
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<tr>
<td>C</td>
<td>Cool, Dry</td>
<td>18 – 22 °C</td>
<td>1000 – 1250 mm</td>
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<tr>
<td>D</td>
<td>Cool, Moist</td>
<td>18 – 22 °C</td>
<td>1250 – 1500 mm</td>
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<td>E</td>
<td>Cool, Wet</td>
<td>18 – 22 °C</td>
<td>&gt; 1500 mm</td>
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<td>G</td>
<td>Warm, Wet</td>
<td>22 – 23 °C</td>
<td>&gt; 1250 mm</td>
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<td>H</td>
<td>Hot, Wet</td>
<td>23 – 24 °C</td>
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<td>J</td>
<td>Hot, Dry</td>
<td>22 – 24 °C</td>
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<td>K</td>
<td>Very hot, Wet</td>
<td>&gt;24 °C</td>
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<td>L</td>
<td>Very Hot/Very Dry</td>
<td>&gt;22 °C</td>
<td>&lt;1000 mm</td>
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**RECOMMENDED SPECIES (SEE ALSO MAPS PAGE 10)**

<table>
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<tr>
<th>ZONES</th>
<th>SPECIES</th>
<th>A</th>
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<td>Cupressus lusitanica</td>
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<td>Maesopsis eminii</td>
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**KEY:**
- ● Species generally well suited to this zone;
-   Species worth trying on selected sites in this zone.
SPECIES SUITABILITY IN UGANDA

Please note that these maps give only a broad indication of which species is best suited to various parts of Uganda. If you are planning to plant a species outside the areas indicated, it might fail: carry out trial plantings first - to test species’ suitability.

Map 5 (Hybrid *Eucalyptus* clones) is speculative at this stage but will be refined when the results of the 2002/03 trials are analysed. Teak was excluded because we are unsure of its suitability at all in Uganda, where the altitude is largely too high for it to grow as a commercial crop.

NB. Careful planning – including environmental assessment – must be carried out before any large scale planting programme proceeds – whatever the species.
PINUS OOCARPA

Family: Pinaceae
Common names: Ocote pine, Nicaraguan pitch pine

Natural Occurrence
POO grows naturally in Mexico, Guatemala, Belize, Honduras, El Salvador & Nicaragua - between Lats. 28°N and 13° N. POO is occurs naturally between 200-2500m asl, although its best growth is found on well drained slopes at around 1500m asl. POO occupies sites with a more severe dry season than PCH.

History of Growing in Plantations
POO has been widely introduced to tropical and sub-tropical countries in Africa, Asia and S. America. It was introduced to Ug in the 1960’s though it appears that these might not have been from the best natural seed sources.

Characteristics & Uses
POO is similar in growth characteristics and habit to PCH, with a light, conical crown. The leaves (needles) of POO are usually in fascicles of 5 (occasionally 3 or 4) and 20-25cm long. POO produces a high quality sawtimber, less prone to splitting and warping than most other pines. Wood density 450-600 kg/m³ and is used for light construction purposes.

Site Requirements:
POO grows in a wide range of soils. Best growth, however, will be on well drained, deep soils at approximately 1500m a.s.l. and MAR >1000 mm. POO can tolerate long, dry seasons once established and will also tolerate temporary waterlogging. PCH performs better on shallow soils.

Seed Recommendations
In international trials, provenances from Nicaragua and Mountain Pine Ridge (MPR), Belize performed better. Most of best local trees have disappeared and thus locally collected seed does not exhibit the excellent stem form and growth of imported PCH seed orchard seed. Until other seed sources are identified, use POO select seed only on steep, shallow sites where PCH will not perform as well.

SUMMARY:
P. oocarpa (POO) yields a high quality sawtimber but is slower growing than PCH. POO is well suited to higher sites and shallower soils but the current lack of genetically improved seed restricts its widespread use in Ug for commercial plantations.

Silviculture:
Very similar to PCH.
Seedlings: POO is easily grown from seed: direct sowing into pots is recommended (ca. 50,000 plants/kg). Mycorrhiza must be added to potting mix. Seedlings should be of plantable size (ca. 20cm tall) within 4 months in Ug. Spacing: 2.7 x 2.7m is recommended (1371 sph) since the available seed is not improved.

Establishment: As for PCH.
Management: Heavy, early thinnings will be important for producing large sawlogs as quickly as possible. High pruning in stages will also be required to produce clean logs. POO at 2-4 years has the ability to respond at ground level after a fire has destroyed the main stem. POO becomes more fire resistant with age.

Yields:
POO is expected to yield 15-20m³/ha/yr - generally less than the PCH from improved seed. Specific seed origins can, however, yield very well.

Common Pests & Diseases:
POO in Ug has been free of major pests and diseases to date. It is susceptible to damping off in the nursery and is reported from elsewhere to be very susceptible to brown needle disease (Mycosphaerella spp.) in the nursery too.

Other Issues:
The growth rate of POO is generally less than PCH, making it the less desirable of the two species. It has been found that POO hybridises naturally with PCH and this fact - combined with the better quality of POO’s wood - means that it could be important for future breeding programmes in Ug. Some of the best POO natural provenances are now classified as P. tecunumanii (P. tec.). The SPGS is investigating the possibility of importing POO (and P. tec.) seed for trials in Ug: in the meantime PCH plantations from improved seed are likely to produce significantly better returns for commercial growers.
PINUS PATULA

Family: Pinaceae
Common names: Mexican pine; weeping pine.

Natural Occurrence
PP occurs naturally in eastern Mexico, where it is a medium-sized tree (occasionally over 30m tall). It is a very variable species with regard to size, stem form and branch characteristics: forking is common.

History of Growing in Plantations
PP has been widely planted in commercial plantations in southern and East Africa and South America. It is a favoured species for pulp (being less resinous than many other pines) and for sawtimber. In South Africa and Zimbabwe, PP has been the focus of intensive tree breeding programmes to improve stem form, volume and branch size.

Characteristics & Uses
PP is easily identified from the drooping (weeping) habit of its foliage. Its needles are borne in fascicles of 4 (sometimes 3 or 5), 15-30 cm long and very thin. The bark of PP is reddish-brown and papery: becoming thick and scaly on older trees. PP's timber has a density of 350-400 kg/m³. Its wood is soft, light, moderately strong and contains very little resin. The wood is very susceptible to blue stain and thus sawnwood must be treated quickly.

Site Requirements:
PP is best adopted to high altitudes with cool climates, which restricts its commercial planting in Ug to the SW of Uganda. PP prefers acidic soils with good moisture supply. PP is frequently planted off-site in Ug (especially at low altitudes) - where it will almost inevitably fail and become prone to various pests and diseases.

Seed Recommendation:
Cloned seed orchard PP seed from southern Africa is strongly recommended. Gains of up to 35% in timber yields have been achieved after two generations of selection and breeding. PP is a precocious seeding species - 5 yr old trees can produce viable seeds.

SUMMARY:
PP is the most important pine species over most of East & Southern Africa. On the cooler, higher sites in SW Ug, PP is the best choice for sawtimber. It can grow very fast and will produce a good quality wood if thinned and pruned on time. Improved (clonal) seed from Southern Africa is available and strongly recommended.

Silviculture:
Seedlings: PP is easily raised from seed (ca. 100,000 per kg): similar to the other pines, direct sowing in pots is preferred.

Spacing: For sawntimber (and when using clonal seed orchard seed) a spacing of 3.0 x 3.0m is recommended. (1111 sph); otherwise 2.7 x 2.7m (1371 sph).

Establishment & Management:
Techniques are very similar to PCH. High pruning is particularly important when growing PP for sawtimber due to its habit of producing large whorls of branches. PP is particularly sensitive to fires as it gets older and develops thinner bark.

Yields:
On suitable sites, PP can grow extremely fast (over 30m³/ha/yr). In Ug, it is expected to yield 20-30 m³/ha/yr on the right sites and with good silviculture.

Common Pests & Diseases:
As an exotic, PP has proved susceptible to many pests and diseases - the major ones being Sphaeropsis sapinea (especially after hail damage), woolly pine aphid and more recently the Sirex woodwasp. PP is a very sensitive species: planting it off-site is highly likely to lead to health problems.

Other Issues:
In favourable areas, PP can become an aggressive colonising species. In Southern Africa, PP is a serious weed, invading grasslands and other vegetation types. The SPGS is already investigating the possibility of importing improved PP seed from breeding programmes in southern Africa.
TECTONA GRANDIS

Family: Lamiaceae
Common names: Teak; Indian Oak

Natural Occurrence
Teak is native to the South Asian and SE Asian region - between Lats. 9° N to 26° N. Much of its natural range is characterised by high MAR and a 3-5 month dry season.

History of Growing in Plantations
Teak has been widely planted in plantations both within and beyond its natural range. It is a major plantation species in Africa, C. & S. America and in the Pacific, with over 2.2M ha planted by 1995. It has not been planted widely in Uganda but significant plantations have been established in S. Sudan and Tanzania and in many tropical W. African countries. Its high quality timber has stimulated major private investment in plantations but yield forecasts are often over-optimistic.

Characteristics & Uses
Teak is a large deciduous tree that grows up to 45m tall and a dbh up to 2.5m. It is sometimes fluted and forked stems are common. Its huge leathery leaves are simple and opposite. Teak yields are of the world’s most beautiful timbers. Its wood is naturally durable, highly valued and used for a wide range of applications. Excellent international markets exist for plantation grown Teak but most buyers require independent Certification (e.g. from FSC - the Forest Stewardship Council).

Silviculture:
Seedlings: Teak is established by raising seedlings but more frequently by stump planting. There are 2-3000 seeds/kg and seed germination is often poor. Stumps are prepared by letting seedlings grow in rows in nursery beds to ca.10 months and then cutting stems back to 5cm above ground and the roots to a length of 20cm.
Establishment: Teak is a highly light demanding, pioneer species. Spacing for plantations ranges from around 2x2m (2500 sph) to 2.7 x 2.7m (1372 sph). Young plants grow quickly and even young trees cast a very dense shade. For the first few years, however, good weed control is important - especially grasses.
Management: Heavy, early thinnings must be carried out or the stand stagnates. A 1st thinning of 50% is often carried out at around 5 years with further thinnings every ca. 5 years to a final crop of ca.200 sph. Rotations expected to be 25-35 years: such long rotations appear necessary to realise the high value of the heartwood. Teak coppices readily from cut stumps.

Yields:
Widely varied growth rates are reported for Teak plantations, with MAI’s of 2-24 m³/ha/yr quoted. With good silviculture (especially well selected seed, intense early weeding and heavy thinnings), MAIs of 8-12 m³/ha/yr could be achieved in Uganda; with rotations around 30 years.

Site Requirements:
The optimum site conditions for Teak are: MAR>1500mm; a 3-month dry season with monthly rain <50mm; alt.<1200m asl.; MAT 22-270 C. It is only suitable for commercial planting in northern Uganda.

Seed Recommendations
Teak exhibits very large provenance differences so great care must be taken to ensure suitable provenances are used for commercial planting. The use of improved genetic seed is essential for successful plantations.

Common Pests & Diseases:
In India, the main pests of teak are white grubs in nurseries, with various stem borers and defoliating insects affecting plantations.

Other Issues:
No improved Teak seed is currently available in Ug and thus care should be taken to ensure appropriate planting material is used before embarking on a major long-term investment in Teak plantations. Work is needed to identify good sources.

SUMMARY:
Teak is widely cultivated in the Tropics in plantations for its high value wood. Many plantations have failed, however, due to poor site selection and use of poor planting stock. There are limited areas in Uganda suited to Teak. It’s long rotation and a lack of good seed also leads us to recommend other species for timber production in Uganda.


**ARAUCARIA CUNNINGHAMII**

Family: *Araucariaceae*
Common names: Hoop pine

**Natural Occurrence**
HOOP has a wide natural altitudinal and latitudinal range in Papua New Guinea and Australia: from sea level to >2400m asl; and from Lats 1° to 30° S.

**History of Growing in Plantations**
For many years, native HOOP stands supplied large quantities of defect-free logs to the Australian plywood industry. Large scale plantations (ca. 50,000 ha) of HOOP have since been established in Australia. In 1971, trial blocks were established in Ug (Kifu CFR) covering 3.65 ha. Although never thinned, this trial shows the huge potential of HOOP on the right site.

**Characteristics & Uses**
HOOP grows into a very large tree (>60m and >1.5m dbh have been recorded). The mature tree is naturally straight, free from branches and with very little taper. The wood has a density of around 530 kg/m³ (similar to PCH): it is not durable but is easy to work and preserve. It is used for a wide range of purposes including light construction, furniture, transmission poles (if treated). It is especially suitable for veneers and plywood because of its ability to grow large, cylindrical and clean trunks.

**Site Requirements:**
HOOP requires deep, moist soils - usually old THF sites.

**Seed Recommendations**
HOOP seed loses its viability quickly but can be cold stored for up to 6 years (-70°C). Heavy seed years only occur every 3-4 years. Only 2nd year cones are collected and before they break up on the tree. Until importations are made, seed for UG plantations is from the thinned trial in Kifu CFR (seed from NFA).

**Summary:**
HOOP can produce a high quality product on fertile sites in Uganda. Establishment costs are high, however, due to slow early growth. Seed loses its viability quickly and is in short supply in Uganda.

**Silviculture:**
**Seedlings:** HOOP seedlings develop a strong tap root and thus the seedlings must be root pruned. There are ca. 4400 seeds/kg. Seedlings should be ready for planting 9 months from sowing.
**SPH:** A spacing of 3.0 x 3.0m (1111 sph) or 4.0 x 3.0 (833 sph) is recommended.
**Establishment:** HOOP seedlings are slow growing at first and then must be well weeded until canopy closure (3-4 years, depending on spacing). HOOP seedlings respond to good weeding. Although tolerant of shade, HOOP grows better in full sun.
**Management:** In Australia a final crop of 400 sph are selected and pruned to 2.4m and 5.4m respectively. Two thinning operations are carried out - the first to 600 sph, the 2nd to 400 sph. HOOP is extremely fire sensitive.

**Yields:**
In Queensland, Australia, 40-50 yr rotations and average MAI of 15m³/ha/yr are reported. MAIs up to 45m³/ha/yr are reported from Papua New Guinea. Based on the performance of HOOP in Kifu CFR, it is expected to achieve MAIs of 20-30 m³/ha/yr on appropriate sites in Ug and with good management, rotations of 20-30 years should be possible. If there were a premium for larger veneer logs, then rotations could be increased accordingly.

**Common Pests & Diseases:**
In plantations in Papua New Guinea and Australia, various rots (fungi) - especially *Phellinus noxius* - causes problems. Ugandan plantations have been free from any serious pests and diseases to date.

**Other Issues:**
*Araucaria hunsteinii* (HUN) is preferred for plantations in Papua New Guinea due to higher growth rates than HOOP, though HUN’s recalcitrant seed has restricted its commercial use in plantations.
**CUPRESSUS LUSITANICA**

**Family:** Cupressaceae  
**Common names:** Cypress; Mexican Cypress; Portugese Cedar; Cedar of Goa.

**Natural Occurrence**
Cypress has a wide geographic and altitudinal range and has been introduced all over the world. It is thought to have originated in Mexico, Guatemala and Honduras, between 15° - 28°N and 89° - 108°W.

**History of Growing in Plantations**
Cypress has been planted widely both as a commercial timber plantation species and as an ornamental. In Kenya it is a major plantation species, with over 85,000ha planted. It has also been extensively planted in Ethiopia and in Mediterranean countries. It has been widely planted for hedges and windbreaks due to its low sensitivity to pruning.

**Characteristics & Uses**
Cypress grows up to 25-30m, with a broadly pyramidal crown. It has a straight stem and a thick, reddish-brown bark that develops longitudinal fissures. It is reasonably fast growing but not as fast as *Pinus patula*, which is suited to similar climates. Cypress wood is highly valued due to its natural durability and its aesthetic qualities. It air dries quickly with little warping; it is easily worked and used for cabinet making, sculptures and also for a range of exterior purposes.

**Site Requirements:**
In its native habitat, Cypress prefers mountainous slopes at medium altitude (1200-3000m asl); it can tolerate a low MAR of 600 mm, provided the rain is well distributed. Cypress is found growing over much of Ug as an ornamental; for commercial planting here, however, it is best suited to the cooler, higher areas in the south-west and west.

**Seed Recommendations**
Cypress is highly variable species, differing significantly in traits such as growth rate, stem form, branching characteristics and resistance to diseases. No improved seed is available in Uganda at present.

**Summary:**
Cypress has been widely planted in higher elevations in East Africa and is prized for its excellent timber. It is fairly slow growing, however, and the Cypress aphid threat raises serious questions over its suitability as a major plantation species in Ug.

**Silviculture:**

**Seedlings:**
Cypress is easily raised from seed. Seed is collected from cones on the tree (flowering only starts ca. 15 yrs) when they turn brown. Seed must be stratified for 21 days at 2-3°C and then soaked in water for 2-3 days prior to sowing. Germination rates can be low. Seedlings should be ready for planting out in 4-5 months in Ug.

**SPH:**
With only unimproved seed available in Ug at present, a plant espacement of 2.7 x 2.7m (1372 sph) is recommended.

**Establishment:**
Cypress is shade intolerant – like pines and eucalypts – and thus must be well weeded in its establishment phase. It is slow growing in the early years.

**Management:**
A heavy thinning regime is recommended for commercial Cypress plantations in Ug – similar to *P. caribaea*. Pruning is important for quality timber production since the trees tend to be very branchy. Pruning in stages up to a third of total height is thus recommended. Cypress is relatively susceptible to fires.

**Yields:**
In East Africa, MAIs of 7-17 m³/ha/yr are reported and rotations of 25-35 years. With good management and on suitable sites, Ug should be able achieve MAIs of >15 m³/ha/yr with a rotation of around 25 years.

**Common Pests & Diseases:**
The Cypress aphid, *Cinara cupressi*, has become a major pest of Cypress in E & S Africa. The aphids feed in colonies, sucking sap from twigs and branches. Heavy feeding can kill the trees. First discovered in Malawi in 1986, it has since spread to other African countries including Kenya and Uganda. Aphid populations are more prominent during dry seasons.

**Other Issues:**
With the threat of the Cypress aphid still around, it would be very risky to embark on widescale Cypress planting in Ug. Other species can outperform Cypress on its favoured sites (especially *P. patula*) although Cypress’s wood is superior.
TERMINALIA SUPERBA

Family: Combretaceae
Common names: Limba, Fraké.

Natural Occurrence
Limba occurs naturally in moist, seasonally deciduous forests throughout West and Central Africa, between Lats. 10°N and 6°S.

History of Growing in Plantations
Limba is one of the few species of which large plantations have been established in tropical Africa – notably Cote D'Ivoire and DRC. Limba was eventually dropped as a commercial timber species in the 1980’s from a major Cote D'Ivoire’s plantation programme due to its poor timber qualities. It has not been widely planted in Ug, although there is a mature trial block in Mukono that shows its promise.

Characteristics & Uses
Limba is a large tree (up to 30m or more), with a long straight bole. It is a moderately fast growing tree and well suited to plantation development in the humid, lowland tropics. Limba wood is relatively soft and light, with a density of 520-550 kg/m$^3$. In some parts of West Africa, Limba is regarded as a highly commercial timber but the wood can often be stained which reduces its value for certain end uses.

Site Requirements:
Limba prefers well drained, fertile soils. It will not tolerate extended dry seasons. It requires areas with high rainfall - MAR >1300mm; alt. < 1000m asl; MAT 24°-27°C.

Seed Recommendations
Considerable variation is known to exist between natural provenances of Limba thus care should be taken before any large scale planting is undertaken in Uganda to ensure a superior seed origin is used. A limited quantity of Limba seed is available from the NTSC, collected from trial plots near Mukono, though its origin is unknown.

Establishment: Limba is a light demanding species and thus must be weeded well especially in the first year or two, until its canopy has closed. In Mukono, Limba has closed canopy within 18 months after intensive early weeding (planted at 3 x 3m). It grows slowly in the few months after planting but then can grow at a rate of over 2 m per year. Limba has been planted in West Africa in both pure stands and in mixed plantings with e.g. T. ivorensis and Khaya grandifolia.

Management: Due to its fast growth and need for light, heavy thinning regimes are recommended. Limba exhibits some self pruning abilities but to obtain large, clean logs, a number of pruning operations will probably have be undertaken.

Yields:
In Cote D’Ivoire, Limba is grown on a 20-25 year rotation; MAs of ca. 15 m$^3$/ha/yr are expected to produce a final crop dbh of 45-50cm and a total timber volume of 330 m$^3$/ha (including thinnings). Similar yields are expected in Uganda.

Common Pests & Diseases:
A range of pests have attacked Limba trees in plantation in West Africa. The main culprits have been stem borers and defoliating insects.