Managing Mahogany Plantations in the Tropics

Field Guide For Farmers




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FOREWORD

African Mahoganies are distributed across West, Central and part of East Africa ranging from Senegal through Ivory Coast, Ghana, Benin, Cameroon, D.R Congo, Sudan and Uganda. A member of the family Meliaceae like *Khaya senegalensis* occurs in semi-deciduous forests, especially in drier types and in savannahs, but the other species usually occur in moist forests in areas with 1200-1800 mm annual rainfall and a dry season of 3-5 months.

In Ghana, these species are becoming scarce in the wake of dwindling forest cover, with illegal logging as a major contributing factor. A reduction in volume of about 100,000 m^3 of exported *Khaya Spp* in 1950 to 17,000 m^3 in 2005, is a clear evidence of its steady decline in Ghana. Declining availability of mahogany wood in the timber market is due to over-exploitation for cabinetwork, furniture, sliced veneer, ship building, open boats, light carpentry work, interior and exterior paneling and joinery, and high export demands in the International Timber Trade. *Khaya ivorensis,* a key species of the African Mahoganies, is included in the IUCN Red list as a vulnerable species because of habitat loss, degradation and extensive selective felling.

There is therefore the need to find the right substitute for the dwindling natural sources of the mahoganies through comprehensive plantation establishment programme. In spite of the problems encountered in mahogany plantations such as pest attack by *Hypsipyla robusta,* plantations in the tropical hemisphere cover more than 100,000 hectares. Efforts geared towards the establishment of indigenous species like African mahogany have been intensified across the tropics. Many International Organizations such as International Tropical Timber Organization (ITTO) have supported projects aimed at increasing forest cover with both exotic and indigenous species. It is now generally accepted that conservation and sustainable utilization of Mahogany can be realized when successful plantations are established.

In recent times, smallholder Timber Plantations for mahogany are of great interest to many organizations including: Forestry Research Institute of Ghana, collaborating foreign institutions such as Michigan Technological University, USA and funding agencies such as the International Tropical Timber

Organization. Through the ITTO Project No: PD528/08 REV.1(F) entitled: "Towards sustainable production of mahogany species in plantations in tropical Africa". Various silvicultural techniques and management of African Mahogany plantation have been researched over recent years and the findings have been presented in this handbook as a field guide for tree growers in general especially smallholder and community farmers. This book was produced at a time when the desire to restore degraded lands with high value species and conserve biodiversity in the African Forests is increasing.

The book is prepared for Farmers and Forest Practitioners as a practical guide about establishing and managing mahogany plantations. It is divided into ten chapters: Introduction, description of different mahogany, seedling handling, description and life cycle of the mahogany shoot borer, maintenance of mahogany stands, silviculture, integrating mahogany into agricultural landscape and wood quality assessment. Techniques presented in this guide are drawn from many sources: the available literature; personal communications with experts and results of field experiments in different ecological zones in Ghana. That general information is complemented with lessons learned from other activities of this project. We expect that the book will be useful not only for farmers at the project sites but also for any smallholders growing mahogany, policy makers, researchers, extension officers, and organizations desiring to see sustainable supply of mahogany from the tropical forest.

Mr. Samuel Afari-Dartey
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Special thanks go to undergraduates and graduates from the Kwame Nkrumah University of Science and Technology and other foreign students from the MTU, USA for their commitment to undertake some aspects of the project as part of their academic work.

The project partners included communities in Oda Kotoamso, Kranka, Osiem Saviour Church and farmer groups at Samreboi. Timber companies such as Samartex Timber and Plywood Company Limited, Asuo Bomoasado Timber Sawmills (ABTS) and African Plantation for Sustainable Development (APSD) were very supportive of the project. The authors are especially grateful to the management of these timber firms. To all scientists and technical staff at CSIR-FORIG, we say thanks a lot.

Contents

1 Introduction

1.1 Why are mahogany plantations important?

- African mahoganies are valuable tropical hardwood species that are of great economic importance to the economy of countries of their natural ranges. Mahoganies belong to the family Meliaceae and include species in the genera Khaya, Entandrophragma and others. They are naturally distributed across the sub-Saharan Africa ranging from Senegal, Liberia, and Cote D'Ivoire through Ghana to Gabon and Malawi.

- There are multiple uses of the mahogany timber due to the aesthetic qualities of the wood making them desirable for domestic and international purposes.

- African mahoganies are widely utilized by local people commonly in traditional medicine. The decoctions of the bark are used for the treatment of ailments such as fever, gastric ulcers, pain after birth and skin diseases.

- The durability of the mahogany wood, good physical properties, and its pinkish to dark brown colour after polishing make it desirable for furniture, decorative veneer and paneling thus increasing the demand for mahogany products in trade.

- The African Mahoganies, like other trees, provide environmental services including water conservation and enhancing benefits

Fig. 1.1 The need to know the toolkits for managing Mahogany plantations

in microclimate.

- For decades in Ghana and other countries where mahogany naturally occurs, the natural forests have been the major source of the mahogany timber to meet local and international demand for their wood products creating an overexploitation pressure on the resource stock.

- Most of the mahogany resource base has dwindled, and the establishment of plantations with these species offers the only viable way to enhance regular supplies for the wood industry.

- Plantations play an important role in local and national economic development. Plantations of mahogany have the potential to improve livelihoods of farmers in rural communities.

Fig. 1.2 Mahogany plantation

1.2 Who are the intended users of this handbook?

This handbook is primarily intended for small-holder plantation developers, farmers, local communities, forest scientists and managers who are interested in establishment of mahogany plantations. It is expected to be relevant to policy makers on issues relating to forest restoration, management and sustainability.

1.3 Why is this handbook needed?

- There is generally a lack of interest among plantation developers in the establishment of indigenous species due to the long rotation and incidence of pest outbreaks in indigenous species plantations.

- Local communities, farmers and plantation developers have limited access to technical information and extension services on best management practices to sustainably manage small-holder mahogany plantations. Acceptable standards for managing mahogany plantations are not well known by farmers.

- Farmers usually manage their plantations with their indigenous knowledge which at times affects the survival of the trees, reducing quantity and quality of expected yields.

- This handbook written in practical language and specifically designed for farmers and local communities who are interested in mahogany plantation establishment.

1.4 What is the scope of this handbook?

- This handbook is written as a guide to educate farmers on best management practices for mahogany plantations in terms of suitable silvicultural techniques, seed collection and seedling production as part of nursery management, planting designs, post-planting care and maintenance through to harvesting. This will enhance restoration and conservation of African mahogany timbers.

- The mahogany management techniques documented in this handbook are simple, cost effective and could be easily applied by farmers and local communities.

- This handbook highlights guidelines for small holder plantation developers, farmers, forest scientists and managers who are interested in establishing mahogany in pure (single species) as well as mixed stands with other indigenous species and Agroforestry farming.

2 Description of different mahogany species

Africa Mahogany (*Khaya spp*) is a member of the family Meliaceae distributed across Africa. It can be found in in Benin, Ghana, Ivory coast, Sudan, Togo, D.R Congo and Uganda, as shown in Fig 2.1

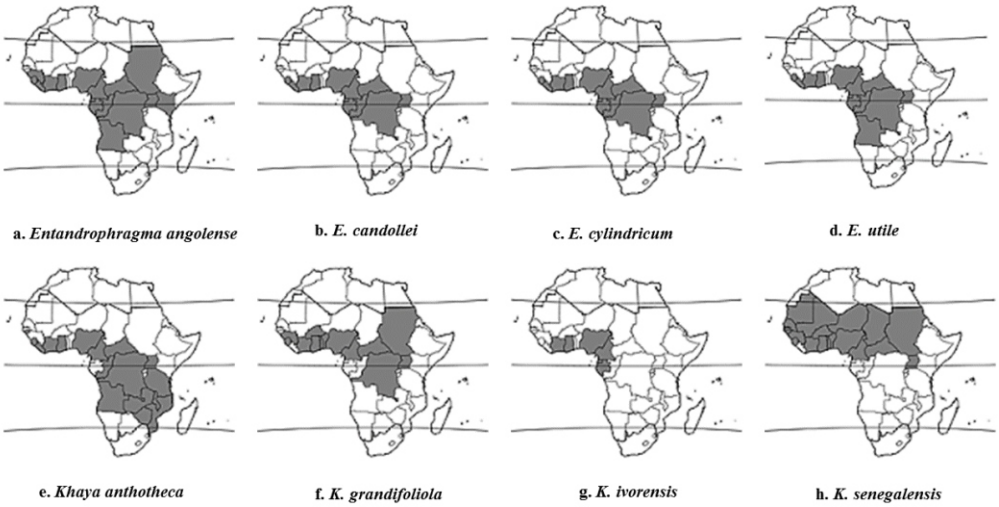

Figure 2.1: Distribution of the eight African mahogany species
Source: www. prota.org

2.1 Khaya anthotheca

Khaya anthotheca locally called *'Krumben'* is one of the most important African Mahogany largely found in Sierra Leone, Congo, Angola, Uganda and in Ghana in the moist semi-deciduous (North West Subtype) and moist evergreen forests with 1200–1800 mm annual rainfall and a dry season of 3–5 months.

The tree grows up to a height of 60m with a cylindrical bole and a girth of about 3m. It has a grey colored, smooth or slightly scaly bark with its slash being deep red. The bark is also thick and bitter. The crown is round with heavy branches. The leaves are pinnate with 2-4 pairs of leaflets and 6-8 pairs of lateral veins. It has small flowers that are monoecious and formed in March usually in fours. The fruits are woody capsules usually with 5 valves, that contain flat golden brown, small seeds engulfed by a narrow irregular thin wing. The tree grows on deep fertile soil and along water bodies.

Fig 2.2a: Leaves of *Khaya anthotheca* Fig 2.2b Slash and bark of *Khaya anthotheca*

2.2 Khaya ivorensis

Khaya ivorensis (Dubini) is found in Ghana largely in wet and moist evergreen and moist semi-deciduous lowland rain forests and areas with average annual rainfall of 1600–2500mm and a dry season of 2–3 months, up to 700m elevation. It extends from West Africa (Ivory Coast) to Central Africa (Gabon).

The tree grows up to 50 m tall and 6 m in girth with long clear bole of 30m. The bark has reddish-brown surface and is slightly rough. The slash is reddish, scented, thick and bitter. The massive crown is open and rounded and leaves inclined upwards. The evergreen leaves are spirally arranged. *Khaya ivorensis* often occurs along watercourses. It prefers alluvial soils which are moist but well-drained, but it can also be found on slopes on lateritic soils. It occurs either in small groups or singly, for the most part of moist valley sites in dry areas.

Fig. 2.3a Leaves of *Khaya ivorensis*

Fig. 2.3b Slash and bark of *Khaya ivorensis*

2.3 Khaya senegalensis

Khaya senegalensis, locally called kutunnkuri, is found in Senegal through Sudan to Uganda. In Ghana, it is found in dry semi-deciduous forest, transitional forest and savanna woodland.

The tree grows up to 35 m tall and 3 m in girth. It has a dense crown and a short bole covered with dark-grey scaly bark. It has a slash color of dark-pink and produces gum. The tree has pinnate leaves with 3-4 pairs of leaflets. The flowers form from January to April. Fruits mature from December to April with 4 valves and seeds are elongated and winged. Aside water bodies, *Khaya senegalensis* are found in low-lying areas.

Fig. 2.5a Leaves of *Khaya senegalensis*

Fig.2.5b Slash and bark of *Khaya senegalensis*

2.4 Khaya grandifoliola

Khaya grandifoliola, is among the most valuable African mahoganies and is locally called 'Kruba'. It is found in the dry semi-deciduous forest of Ghana with an average annual rainfall of about 1200–1800 mm and a dry season of 3–5 months. It occurs up to 1400 m elevation. Sometimes, it can be found on rocky and hilly parts of moist semi-deciduous forest. The species also extends from Guinea to Angola and Uganda.

Tree height is up to 40 m tall, diameter up to 2 m and buttresses can be 3 m high. The bark is rough and greyish brown with slash being reddish with white streaks, scented and viscous exudate. Leaves are spirally arranged with 3-5 pairs of leaflets sometimes with 12-15 pairs of well-defined veins. Flowers are unisexual and fruits contain disk-shaped, strongly flattened, narrowly winged all around the margin and brown seeds. It does well in moist but well-drained

Fig.2.4a Leaves of *Khaya grandifoliola*

Fig.2.4b Slash and bark of *Khaya grandifoliola*

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3 Seeds and Seedling Production

3.1 Is there any need to prepare seeds?

- Trees exhibit their growth and physical appearances from their parent trees. The expression of such characters are influenced by their genetic makeup and the environment or surrounding in which they are grown, normally referred to as genetic and environmental factors.

- The type of seeds from which seedlings are produced determines whether the trees will be relatively fast growing species which are healthy (develop resistance to pest and adverse environmental conditions). Thus, the ability to select good seeds from the lot for nursery establishment influences the overall quality and productivity of a stand.

- Seeds of high quality produce seedlings with good growth characteristics for planting. When the seedlings are planted on suitable sites their growth is rapid and have fair growth on unsuitable sites.

- Seedlings raised from poor quality seeds usually show stunted growth even on suitable sites as the genetic factors may mask the surrounding conditions for growth resulting in poor growth and yield. Low quality seedlings rarely grow and survive on any type of land.

- The planting site and time of planting also affect seedling growth, however, farmers and plantation developers can be assured of high yielding seedlings if good quality seeds are selected and well managed in nurseries for planting.

3.2 Seed sources/ Seed collection

3.2.1 Where can we obtain seeds for planting?

Seed trees are trees selected and maintained for producing seeds. These trees are also called seed sources. There are different areas from where seeds can be obtained for planting. Selection of desirable trees depend on availability, cost of production, and others factors.

- Seeds can be collected from mature seed trees of good growth which have regular fruiting and flowering(depending on the species' flowering and fruiting pattern) characteristics and are free from pests and diseases. In the natural forests, many trees with dominance in height and diameter growth (superior or plus trees) are identified and marked for seed collection yearly.

- The best quality seeds are from seed orchards, including hedge, seedling and clonal seed orchards. However, seeds from these sources are of limited supply and are very expensive to manage.

- Depending on availability, seeds should be obtained from certified seed production areas or institutions. Selected trees that are accessible to farmers can be managed as seed trees. Seeds can also be provided by institutions and programmes that support farmers and plantation establishment.

- When buying seeds, they should come from a certified superior or reliable source. The ecological conditions of the seed sources should be considered including site, altitude, climate, and soil type. Care should be taken to prevent seed stress which can affect seed viability.

- In areas where it is difficult to obtain seeds from certified seed sources, the convenient and most cost-effective option is by identifying and collecting seeds from the best quality seedtrees (mother trees) in the local area.

3.2.2 Seed source classes

Seed sources can be individual trees on agricultural land or in a natural forest or a group of trees that grow together in one area. The seed sources for reforestation programmes can be classified into seven categories as follows:

1. Seed stands that are identified in natural forests or plantations to serve as seed sources for planting are classified as **identified seed stands** (ISS). Identified seed stands provide average quality of seeds.
2. A **selected seed stand** (SSS) provides seed sources with better quality than the average stand.
3. A stand established specifically as a source of seeds is grouped as a '**seed production area**' (SPA). It can also be created by culling poor quality trees from an SSS or ISS.
4. A **provenance seed stand** (PSS) provides seeds generated from seeds that were collected from the natural distribution range (the provenance) of the species of interest.
5. A **seedling seed orchard** (SSO) provides seeds generated from the seeds with good performance or 'plus' trees'.
6. A **clonal seed orchard** (CSO) provides seeds produced from vegetative materials (usually stems, leaves or roots) of plus trees.
7. A **hedge seed orchard** (HSO) provides vegetative materials, usually for cuttings or tissue culture, generated from seeds or grafts from trees in a CSO or SSO.

3.2.3 How are seedtrees selected?

Trees that demonstrate superior growth performance are usually free from pests relative to the companion trees within the stand. These are considered as plus trees to be used as seed trees. Desirable traits of plus/seed trees include but are not limited to the following:

- Good height and diameter growth above the average tree in a stand;
- Long, clear bole (trunk) that will fetch a good price at market;
- Uniform crown, without heavy branches or double stems;
- Freedom from pests, pathogens and disease; and
- Mature tree with good quality timber that fruits regularly to produce seeds.

In evenly aged stands, tree diameter and height are the important characteristics for selecting seed trees. Seed trees can be selected from farms or forests surrounding us if the following requirements are met:

- The seed tree must grow with other adult trees within 100 m. Seed trees growing alone should be discarded even if the tree is large and straight. Such trees are mostly self-pollinated and produce seeds with poor genetic quality.
- Seed trees selected from a garden should be well formed and disease-free.

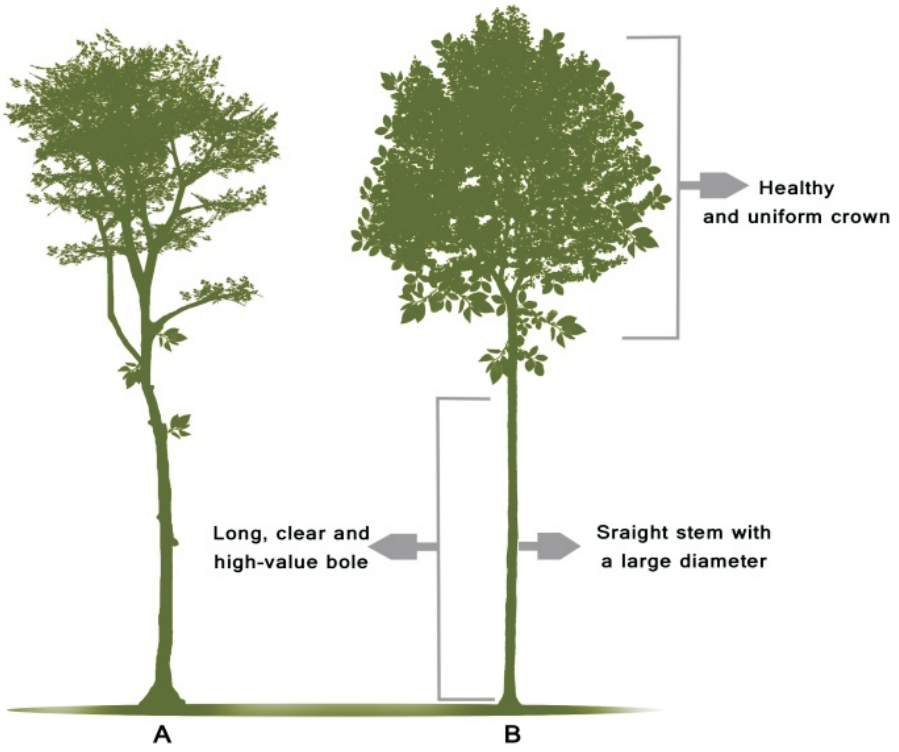


Fig. 3.1: **Selecting appropriate seed tree**

A. An unsuitable Mahogany tree
B. suitable Mahogany seed tree

3.2.4 Seed collection

The timing of seed collection is important

- Harvest mahogany fruits when they are mature and ripe showing a greyish brown colour
- A white or light colour indicates that the fruit is unripe. Immature seeds have low germination viability.
- Seeds should be collected from plus trees that have already produced healthy fruit (seeds) for at least two or three years.
- Mahogany trees usually begin to produce viable, healthy seed crops from15-30 years old. Seed production fluctuates considerably from year to year due to its mast fruiting pattern.
- To improve the range of seeds you collect, take seeds evenly from all parts of the canopy, the top, sides and bottom. These parts may be pollinated at different times with pollen from different trees.
- A tree climber is required to climb the mother tree to cut the branches where the seed are well stacked and pick the isolated seeds.
- The ground around the mother tree is cleared and a sheet of plastic or tarpaulin is placed on the ground under the canopy of the mother tree to easily collect the seeds that fall and to keep them clean.
- Ripe fruits that are cut or loose fall on the tarpaulin. Ideally fruits that fall on the tarpaulin are collected. Discard fruits (seeds) already on the ground because they may come from undesirable or pest/disease infected trees.
- Good seeds can be collected from around quality mother trees maintained within seed stands, seed protected areas or seed orchards. These naturally fallen seeds should be stored in a separate container without mixing them.
- Collect seeds from at least 10 trees to enhance genetic diversity.
- Seeds from a single tree growing alone will usually produce a stand of trees of generally low quality. Seedlings from such trees if planted in an area may produce a plantation that is not resistant to pests, diseases and climate change.
- Seeds from closely related parents should be avoided. Good seed trees should be at least 50m apart.

3.2.5 Seed handling

- Choose only healthy seeds from ripe fruit. Seeds should be extracted from the capsules as soon as possible to prevent rotting.
- Sun-dry the seeds out in the open over a flat area. Dry the seeds for 1-2 days in the sun, stirring them 3-4 times during the day to keep them separate. This will reduce the water content of the seeds to about 10%.
- Seeds can also be spread in a well ventilated room for one and half to two months to dry.
- Clean the dried seeds by removing any dirt or litter mixed in with the seeds.
- One kilogram of mahogany seeds usually contains 1500-2000 seeds.
- The age or size of the tree probably affects the size of the capsule and thus the seed weight.

3.2.6 Seed Storage

- Store dried seeds in a sealed container in an air-conditioned room or refrigerator to 2-8°C and constant low humidity to avoid chilling damage.
- Seeds can be stored for a year or more.

3.3 Seed sowing

3.3.1 Sowing of mahogany seeds

Mahogany can be sown in beds, containers, and trays. Sowing in beds allow the development of fibrous rooting system of seedlings. In areas where bare rooted planting stock has low survival, container stock is used for planting.

How are seeds sown?

- Prepare the sowing medium. Usually, a light, well drained soil (such as river sand due to its good drainage and high aeration) give best results.
- Sterilize the sowing medium by sun drying or heating to dryness over fire and treat it with a fungicide (e.g. dursban 4E) to kill fungals pathogens.
- Add water to the sowing medium to saturation.

- Place the treated seeds into the sowing medium
- Plant the seeds as deep as the seed diameter, and then sprinkles and over the seeds to cover them with a layer of 1–2 cm.
- Seeds can also be sown in containers or pots with a maximum of two seeds per pot.
- Seeds are sown at 5x10cm and seedlings are transplanted to plastic pots when they are about 5-10cm high.
- The sowing bed must be weeded to avoid competition and watered daily to keep the medium moist.
- Seeds germinate within one to two weeks after sowing.

Normally germination does not occur uniformly. Some seeds extend the germination period after sowing. The germination rate and percentage are determined by the age of the seeds(seed freshness), seed treatment during drying and conditions in the sowing bed.

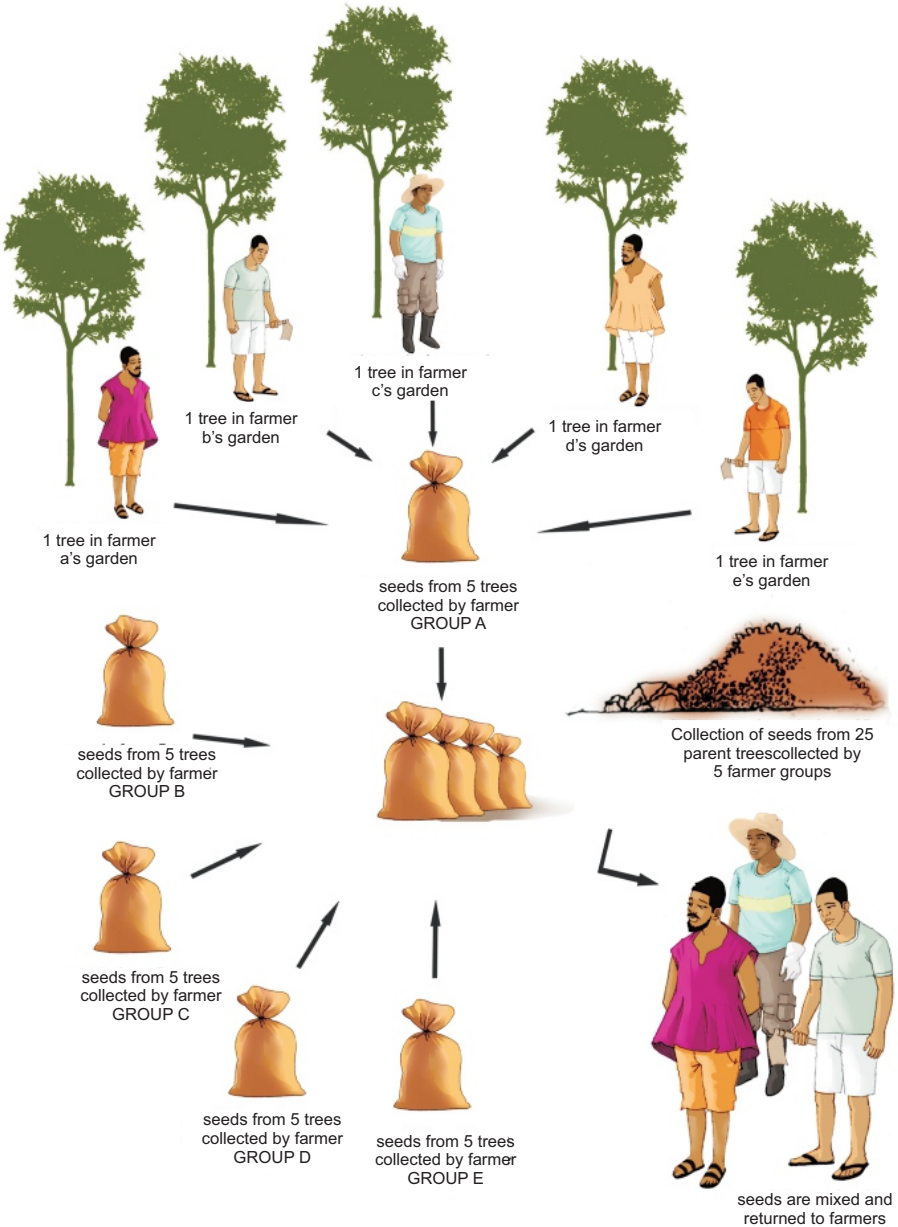


Fig. 3.2: Collecting quality seeds in collaboration with a group of farmers

Fig.3.3: High quality seeds

4 Seedling Handling

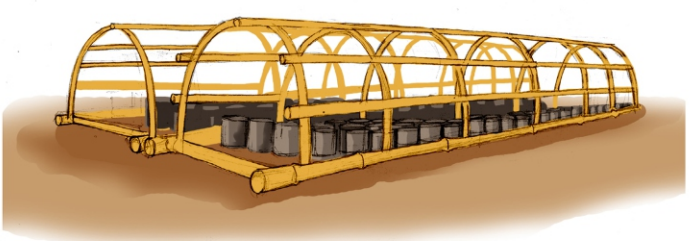
4.1 How to transplant germinants

- Prepare nursery medium using topsoil.
- Add fungicide at prescribed rates to create a sterile environment for the germinant and place the medium in polybags.
- The germinant can be transplanted 3–5 days after germination or after a pair of leaves have formed.
- Transfer the germinant to polybags in the morning before 8:00 a.m. or in the afternoon (around 17:00p.m.) when temperatures are low.
- The germinant is lifted from the sowing bed by gently holding its leaf or the seed.
- Transplant germinant immediately after lifting to avoid root desiccation.
- After transplanting, the seedlings and medium are evenly watered.

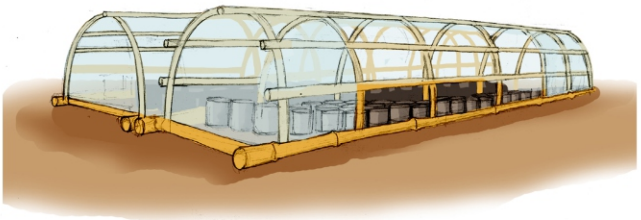
4.2 Seedlings raised from shoot cuttings

4.2.1 Where can we find good cutting materials?

- Shoot cutting materials can be obtained from coppices, seedlings or a hedge orchard.
- ·The cuttings should originate from the best superior mahogany trees or selected clones.

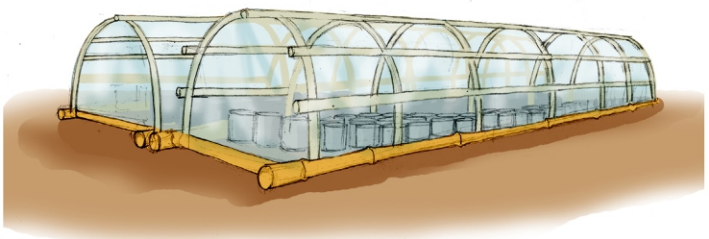


1 Create covering frame from bamboo and arrange polybags inside.



2 Seal both ends of the frame with plastic.

3 Cover the cuttings with plastic that opens and closes easily



4 The sealed transparent plastic cover maintains high humidity within the cuttings bed

Fig.4.1: Techniques for covering cuttings' bed with plastic

What is a clone?

A clone is a group of trees or seedlings that are genetically identical, produced through vegetative propagation rather than from seeds from a single tree. Clonal propagation can be done by stem and root cuttings, grafting or tissue culture.

4.2.2 How to choose and prepare plant material for cuttings

- Best quality mother trees of 1-15 years old can be coppiced or bended to resprout for cutting collection.
- Actively growing shoots of the coppiced and bended trees are harvested and cut into single node cuttings.
- The leaf laminar is trimmed to retain about one-third the leaf portion about 30-60 cm^2 depending on the size of the leaf.
- Cut the base of the shoot squarely with a sharp knife or cutter.
- Wet the base of the cutting and dip in rooting hormone preferably in dole butyric acid (0.8% IBA) for 5–10 minutes or dip it in a solution. Prepare this solution by dissolving 0.02 g of IBA in 2 tablespoons of ethanol mixed with 1 litre of water.

4.2.3 How to plant cuttings

- A simple non-mist propagator is prepared. Rooting medium containing river sand, topsoil and/or mixture of the two can be used for rooting the leafy stem cuttings.
- Plant the shoot cuttings that have been dipped in the IBA solution or powder in the prepared media in the non-mist propagators.
- Water the stem cuttings daily.
- Maintain temperatures of 22-24^{0}C and humidity of 70-80% in the propagator to enhance root and shoot development.
- If there is an indication of fungal attack, spray cuttings with a fungicide at prescribed rates.

4.2.4 Caring for rooted cuttings

Before planting in the field, gradually acclimatize the cuttings to dry and open conditions, which are different from the conditions under the propagators. Techniques for acclimatization include:

- Separate rooted cuttings and place them in a separate bed in a shady area.
- Separate unrooted cuttings and place them in other beds to continue the rooting process.
- Keep rooted cuttings under a plastic cover for 3 days to adapt to the new conditions in the planting bed.
- Open the cover gradually at a rate of 10cm per day. After 10 days the cover can be completely removed.
- Keep the cuttings in the shady area without cover for 2 weeks.
- Move the seedlings raised from cuttings to an open area until theyare ready for planting.

4.3 Seedlings from other sources

4.3.1 Are there other techniques to produce seedlings?

Yes, seedlings can come from wildings and stumps. Several other techniques for propagating mahogany seedlings exist including in-vitro micropropagtion (tissue culture) which requires higher technology and are more expensive in terms of training, expertise and equipment. These techniques are quite sophisticated and as such unsuitable for individual farmers and small holders.

4.3.2 How can we prepare seedlings from wildings?

Wildings are naturally regenerated seedlings that grow under or near mahogany trees after dispersal of the seeds. They are common in natural forests, plantations

and orchards.

- Wildings that have 2–3 pairs of leaves, a straight stem which are healthy and fast-growing are selected as seedlings.
- It is suitable to collect wildings during the rainy season.
- Cut the leaves in half and prune some of the fibrous roots.
- The wildings are transplanted immediately into polybags containing a medium such as river sand and topsoil.
- The wildings are nurtured in the nursery and can be transplanted after 3–4 months.

4.4 How to maintain seedlings in a nursery

Good maintenance of mahogany seedlings is essential for the production of healthy and fast growing plants.

- Maintenance activities include watering, weeding, fertilizing and other standard practices including spacing, root pruning and controlling pests and diseases.
- Water twice a day in the morning and evening, or at least once a day, preferably in the morning.
- Provide adequate shade using bamboo slats or fine mesh netting for the young seedlings to prevent desiccation.
- Fertilize the seedling bed 1 month after planting using NPK fertilizer (about 1g or ¼ teaspoon per seedling). Repeat when seedlings are 2 months old using 2g of NPK fertilizer per seedling, approximately ½ teaspoon.
- Remove weeds from in or between polybags that may compete for resources for growth of the seedlings
- Prune the seedlings once the seedling is 20 cm tall to remove old, dry,

rotten or diseased leaves, leaving the top three pairs of leaves.

- Prune the roots that grow out of the polybags regularly to encourage roots to grow into the soil.
- Do the last trimming at least 1-2 weeks before distributing the seedlings.
- Increase the spacing between seedlings when the leaves of adjacent seedlings start to cover each other.
- Pests and diseases are best controlled by applying pesticides and fungicides.

4.5 When seedlings are ready for planting, what do they look like?

- Stem diameter and seedling height are not the best indicators to determine seedling quality.
- Good quality seedlings that are ready for planting have the following features:
- Strong fibrous root system that is more coiled
- When seedlings are removed from the polybag, the medium and the roots maintain a cylindrical form which is porous and not compacted.
- A single, strong and woody stem
- Seedlings are upright and strong
- unbranched with a balanced stem diameter and height.
- Healthy new leaves with no
- evidence of harm from pests or diseases.

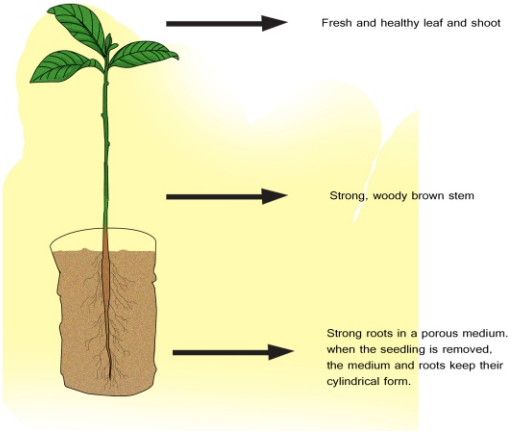


Fig 4.2: A good seedling for planting

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5

Description and Life Cycle of The Mahogany Shoot Borer

5.1 What the mahogany plantation farmer must know about the mahogany shoot borer

The mahogany shoot borer, *Hypsipyla robusta,* usually completes its life cycle in 5 to 8 weeks, depending on climate and availability of food. An individual female lays an average of 50 eggs. Eggs are laid singly, or occasionally in clusters of three to four, on or near leaf axils, scars or veins. The eggs are oval in shape; measuring 0.64-0.70 mm in length and 0.48-0.53 mm in width. The eggs stage lasts between 3 and 5 days. The newly hatched larvae are small and highly mobile, and move towards new shoots and burrow into the stem or leaf midrib and the leaf axil. After 2-3 days, those larvae that have invaded leaves or small side shoots re-emerge and tunnel into the terminal shoot of the stem or branch. The larvae cover their entrance hole with a protective web consisting of plant particles and frass about 3 days after entering the terminal shoot. The remainder of the larval stage is spent boring into the primary stem or branches of the tree and feeding on the pith. When the shoots are not available, the larvae may feed on sub-cortical tissue, sometimes boring into the thick bark. They have also been observed feeding on young leaves brought together in webs.

The larvae usually pupate in the galleries bored into the stem of trees or may pupate in the soil beneath attacked trees. Last instar larvae spin a cocoon prior to pupation. The pupal stage last 8-10 days and a sex ratio of 1:1 is common. Most adults emerge during sunset. The developmental period of egg to adult stage lasts between 26-40 days on plant material. Courtship activities are minimal,

Fig. 5.1 *Hypsipyla robusta* larvae

males are attracted to calling females, which adopt a calling position with the abdomen bent upward between the wings. The calling results from the release of chemical sex pheromones that are attractive to males.

The adult moth is nocturnal and the duration of mating ranges between 1.5 and 3 hours. Peak flight activity occurs between 24:00 and 05:00; and flight activity ceases when temperature falls below 15^0C and during high precipitation. The moth is capable of flying several kilometres in search of food. Females are particularly attracted to new foliage for oviposition.

The number of generations a year varies with climatic conditions and availability of new shoots. Insects are able to continuously attack trees in areas that are wet all year round and switch from shoot to fruit in areas with a pronounced dry season. Attacks are more numerous in the rainy season, when new shoots are produced.

Attacks are more numerous in the rainy season, when new shoots are produced.

5.2 Breeding of *Hypsipyla robusta* on artificial diet

Oviposition takes place after 1-3 days when newly emerged adults are caged together. Eggs are laid singly or in batches of 2-3 eggs. They are oval and creamy white when freshly laid. Fertile eggs change colour to pinkish brown within 24hrs whereas infertile eggs remain creamy white after the same period. The number of eggs laid by female varies between 39 and 124

Table 5.1 Oviposition, fertility and hatchability of *Hypsipyla robusta* in laboratory rearing

Experiment	No. of fertile eggs/fmale	No. of infertile eggs/ female	No. of larvae emerged from fertile eggs	Hatchability %
1	45	85	26	57.78
2	15	80	13	86.67
3	108	14	104	96.20
4	201	30	116	57.71
5	68	0	62	91.2
Total	437	209	321	73.46

Fig.5.2: Stages of the development of *Hypsipyla robusta*

5.3 Natural enemies of *Hypsipyla robusta*

The mahogany shoot borer, *Hypsipyla robusta,* is able to devastate young plantations of the potentially valuable timber species. However, there are a number of natural enemies that can suppress the population explosion of this major mahogany pest. Table 5.2 shows the identity of parasitoids encountered in the field. The Tachinidae parasitoids were associated with larvae collected from fruits, shoots and bark, but all the other parasitoids were associated with larvae collected from shoots and bark of mahogany.

Table 5.2: Parasitoids associated with *Hypsipyla robusta*.

Parasitoid	Family: Order	Stage parasitized
Eurytoma sp.	Hymenoptera: Eurytomidae	Larva
Prosturmiaamicula (Mesnil)	Diptera: Tachinidae	Pupa
Caldurciaauratacauda (Curan)	Diptera: Tachinidae	Pupa
Macrocentrus sp.	Hymenoptera: Braconidae	Larva
Protomicroplitis sp.	Hymenoptera: Braconidae	Larva
Hexamermis sp.	Nematode: Mermithid	Larva

The weaver ant is a promising biological control agent of a shoot borer, *Hypsipyla robusta*, on mahogany, but techniques to conserve ant colonies redistributed to mahogany plantations have not yet been developed.

5.4 Fungal pathogens

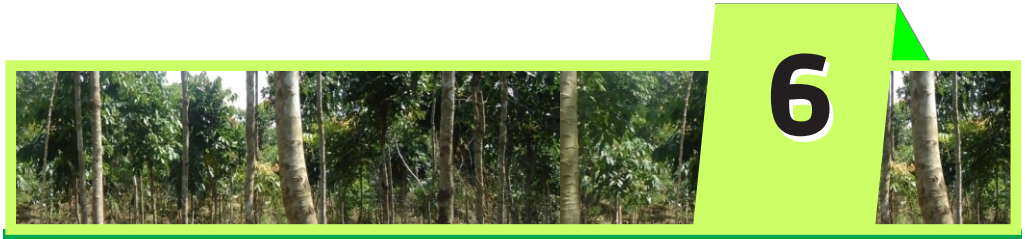
Table 5.3 shows fungal pathogens identified with *Hypsipyla* cadavers. Apart from *Fusarium proliferatum,* which occurred on *Hypsipyla* eggs, the rest of the pathogens were associated with *Hypsipyla* larvae. The effects of these fungi and their role in larval mortality are unknown.

Table 5.3: Fungal Pathogens associated with *Hypsipyla.*

Pathogen	***Hypsipyla* stage infected**
Beauveria bassiana (Bals)	Larva
Fusarium verticillioides (Sacc) Nirenberg	Larva
Fusarium solani (Mart)	Larva
Fusarium proliferatum (Matsushim)	Egg
Nirenberg	

Fig. 5.3: Diseased Mahogany leaves

Fig. 5.4: Healthy Mahogany leaves



6 Maintenance of Mahogany Stands

6.1 What activities are part of mahogany stand maintenance?

Mahogany grows fast and produces high-quality timber when the land and the trees are adequately maintained. Activities involved in maintenance include weeding, fertilizing, beating-up or infilling, pruning, thinning, maintaining coppices and controlling pests and diseases.

6.2 Weeding

Should the understory, shrubs or grass around the mahogany stand be cleared?

It is very important to ensure regular clearing of weeds, shrubs or grasses under established mahogany trees in order to allow sufficient light to reach the young mahogany crowns

- In young mahogany plantations weeds including herbaceous vines, creepers, shrubs (eg. *Chromolaena odorata*) and grass accumulates under the trees to interfere with their normal growth and development. These weeds compete for resources such as light, water minerals and other soil nutrients essential for the trees growth.
- If the weeds are left uncontrolled, they could hinder growth, resulting in stunted growth and in extreme cases kill the mahogany trees.
- Weeding can be done less frequently in mature mahogany plantations after canopy closure.

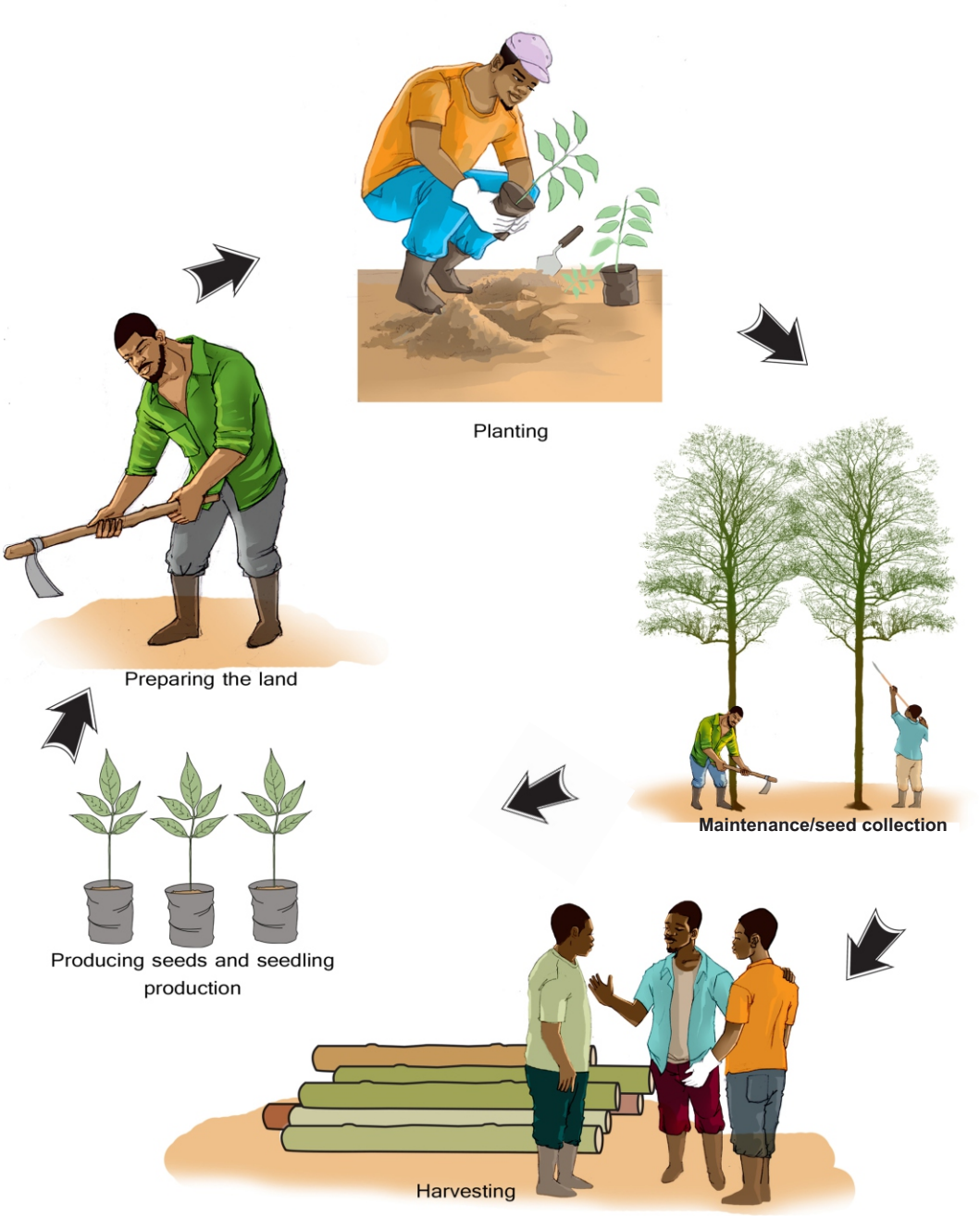


Fig. 6.1: Activities in Mahogany silviculture management

- Usually, understory weeds below mature trees die by themselves.

Frequent weeding on a 2-3 monthly cycle has been found to produce significant improvements in height growth of the mahogany trees.

- Weeding of planting lines is needed in logged forests.
- As an alternative, weeds can be effectively controlled by practicing an agro-forestry system where mahogany trees are intercropped with agricultural crops. In these cases, tilling for the crops also serves as weeding for the trees.

6.3 Fertilizing

6.3.1 Why do trees need fertilizer?

- Most trees that are planted on fertile lands (rich soils) need not be fertilized because the soil qualities suitably enhance the growth of trees.
- Unfertile land requires fertilizer application with NPK to correct nutrient deficiencies and is recommended to apply it when the trees reach 1, 2 and 3 years.
- The suitable dose of NPK per tree are 50g in the first year, 100g inn the second year and 150g in the third year per tree.
- Organic manure or compost can be applied at a dose of 10 kg per planting hole before planting the tree.
- Mahoganies establish well on a wide range of soils from well drained and fertile soils including clay-loam, to sandy. The preferred soil pH is from alkaline to neutral
- It is appropriate to treat acidic soils (low pH) or soils with limited calcium (Ca) with lime (dolomite) to raise the pH.
- In Agro-Forestry systems, applying fertilizer benefits both mahogany trees and the agricultural crops.
- To apply fertilizers make holes with a small wooden stake on either side of the tree or crop.

- Another way is to apply fertilizer in holes 10-15 cm deep that ring the mahogany tree at a distance of 0.5–1.5 m from the stem; about the width of the tree's canopy.

6.4 Pruning

6.4.1 Why is pruning necessary?

- Pruning is an essential part of the maintenance of mahogany plantations.
- Pruning involves the removal of branches which increases clear bole height and reduces the susceptibility of the trees to pest attack.
- Removing multiple branches or shoots enhances the growth of the main stem and tree canopy.
- Sections of wood removed through pruning can be used for fuelwood or charcoal production which provides additional revenue for the farmer and other smallholders.
- Pruning minimizes the frequency of forest fires spreading through the tree crown to damage the plantations.

Fig. 6.2 Pruning of a Mahogany tree

6.4.2 How to prune

A

B

Fig. 6.3 Pole pruners (A) and pole saw (B) used to prune branches.

- Pruning commences in the third year and it is advisable to prune early in the rainy season, around August.
- Pruning along more than 50% of the height of the tree can hinder the tree's growth hence multiple sprouts can be removed leaving one or two main stems.
- Branches and shoots are cleared from the lower half of the tree while the developing shoots are still young and small.
- Pruning should be done close to the main stem without cutting the branch collar.
- The branch collar is the slight swelling at the base of the branch where it grows from the stem.
- Pruning the branch collar causes wounds on the stem that heal more slowly and also makes the tree more susceptible to pests and

- susceptible to pests and diseases.
- ·Delayed removal of large branches creates knot defects in the wood and the trees become more susceptible to pests and diseases. Frequent pruning improves the productivity of the mahogany stand.

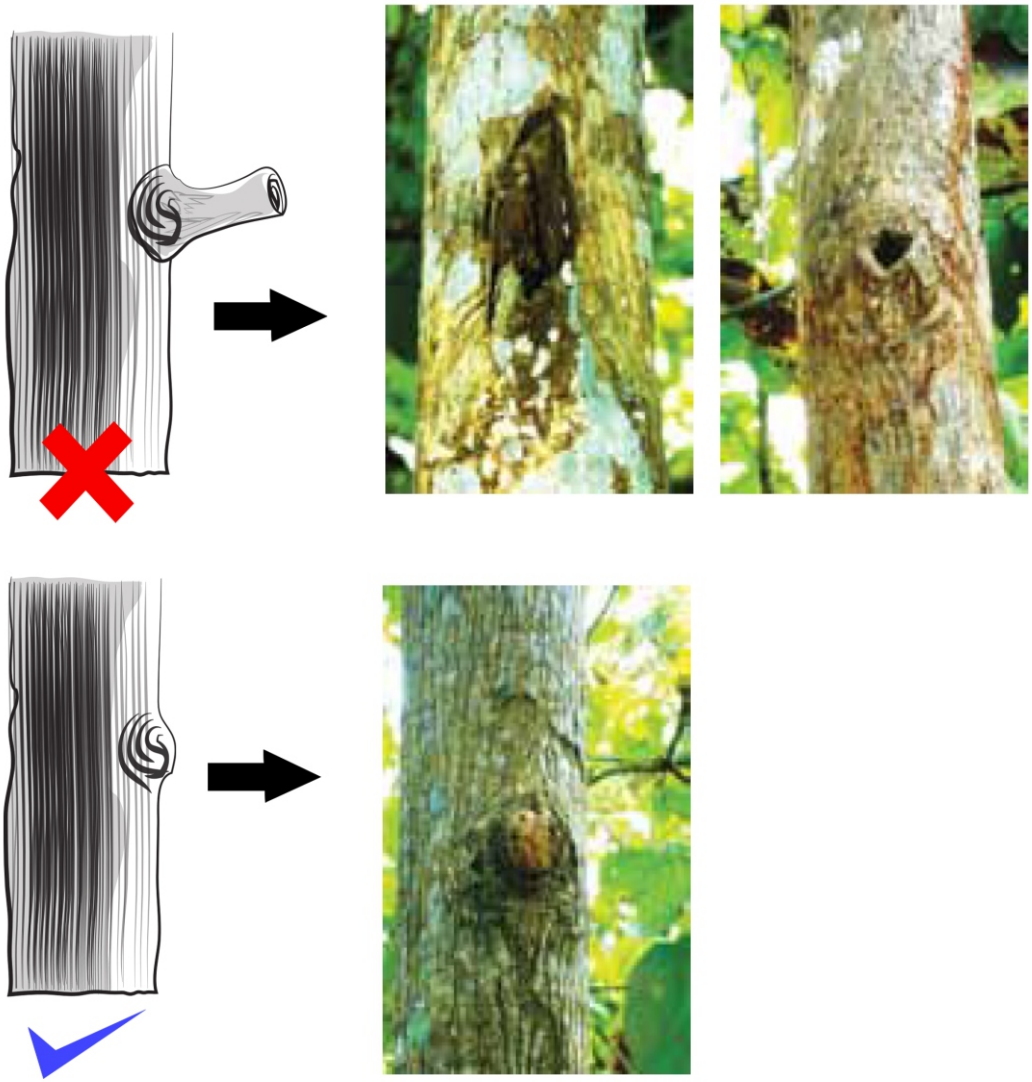


Fig. 6.4 Effect of pruning on stem quality

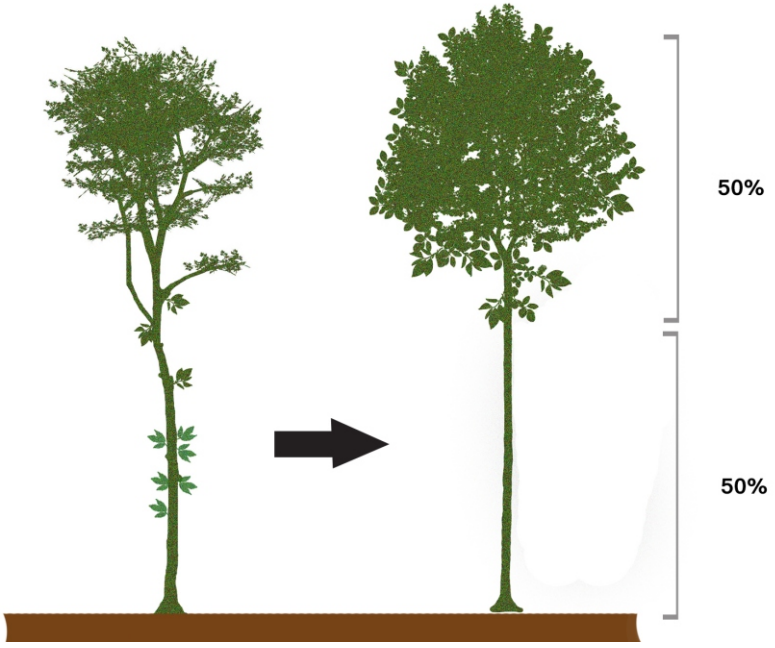


Fig. 6.5 Recommended height to which branches should be pruned

Fig. 6.6 Equipment suitable for pruning

• Pruning is done using special tools: pruners, secateurs and pruning saws. Small, young twigs can be pruned with a sharp sickle or machete.

• It is appropriate to cover each pruned area of the stem with a special paint or tar to reduce its risk to infection.

6.5 Thinning

6.5.1 Why are plantations thinned?

- Thinning is done in a closely spaced stand (spaced 1mx1m, 2mx2m) to reduce the number of trees to create more space for the crown and root development.
- Thinning minimizes the competition for light, water and nutrients which causes slower tree growth, tall and skinny stems.
- The removal of stressed, unhealthy and slow-growing trees encourages better growth for the remaining good quality trees that are fast-growing and healthy.
- Thinning increases the trees growth, prevents easy spread of disease from one tree to the other and ensures even distribution of trees.
- By thinning, the harvested trees can be sold to raise income through fuel wood and charcoal production.

6.5.2 Best practices in thinning mixed mahogany plantations

- Trees that are defective (diseased), slow-growing or with poor form are normally thinned to provide space for good quality trees.
- In mixed mahogany stands, at close spacing (2-3m) it is good to thin within 5-10 years after most trees in the stand reach the age of 15.

- It is advisable to delay thinning to encourage recovery of vertical growth and improved tree form if the trees have been attacked by the shoot borer.
- Thinning should be conducted more frequently if only a few trees are cut per thinning.
- Thinning should be done at 5-10 year cycle depending on the growth rates.
- In understocked plantations, there is no or less competition among the mahogany trees and therefore thinning is not necessary.
- The number of trees left after thinning can be based on the height of the trees, which is influenced by age and site fertility (site index).
- In general, maintenance of mahogany stands at a basal area of 25-30m^2ha^{-1} is recommended
- Mahoganies that are fast growing close canopy in about 8 years and in such cases reduction in density from 333 stems ha^{-1} to 150-200 stems ha^{-1} is recommended.

Table 6.1 Types of thinning and stocking density of Mahogany stand

Age/Yrs	Stocking Density	Type of thinning
5	1600	
15	1000	Selective
21	500	Crown
28	250	Crown
35	150	Mixed
50	120	Regeneration

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6.5.3 How to thin unevenly aged mahogany trees

- In a monoculture system with evenly aged and regularly spaced stands, thinning is relatively easy to perform.
- Stunted or slow-growing trees often distinguish themselves from the average and from fast-growing trees of the same age. The relatively short and poor performing trees are thinned leaving out the best ones.
- Thinning is more difficult for unevenly aged and irregularly spaced stands

6.5.4 How to thin unevenly aged mahogany stands

Thinning should be done to maximize the size and quality of the final tree crop.

- Kowledge about the growth of each tree allows us to assess how cutting one tree affects the surrounding trees.
- Mahogany requires considerable light to grow. Overlapping canopies indicates that the stand should be thinned.
- It is necessary to cut diseased trees, trees with poor stem quality, and those trees growing under the canopy. Trees do not require thinning if only the bottom section of the canopy is in shade.
- Seedlings or young trees growing in an open area should be retained to grow.
- To maintain the diversity of tree size and age, there should be equal representation of different ages and diameter classes of the remaining trees for varied and sustainable harvesting regimes.
- Selective thinning of mahogany plantations can be planned and conducted to generate income for households. This generates commercial gains from the sale of harvested trees whiles increasing the value of the remaining trees at the same time.

6.6 Beating-Up/ Infilling

6.6.1 What is beating-up and why is it necessary in managing mahogany plantations?

- Beating-up or infilling is the replacement of dead plants with new seedlings.
- It is usually done a few months after planting to maintain the stocking density and intended spacing of the mahogany trees in the plantations.
- Beating-up is also useful for replacing, unhealthy or poorly growing plants and seedlings that might have broken during the planting activities.
- It is appropriate to conduct beating-up in the rainy season to enhance the survival.

Fig. 6.7 Beating up in plantation

6.7 Controlling pests and diseases

6.7.1 What pests frequently attack mahogany plantations?

The commonest pest of mahogany in almost all places within the tropics is the shoot borer, *Hypsipyla robusta*.

- *Hypsipyla robusta* is prevalent in mahogany plantations in Asia, Africa and pacific regions
- The shoot borer larva destroys terminal shoots that are actively growing at young stages, sapling and mature stages of the trees growth.
- The shoot borer attacks seed and fruit capsules and bore into the fresh, succulent shoots of the mahogany species, killing the first few centimeters of the shoots.
- Attacks result in the development of numerous secondary shoots, and a poorly formed tree develops, reducing the quality and economic value of the timber.

Fig 6.8

Fig 6.8b

Fig. 6.8c

Fig 6.8a,b,c: Mahogany shoot borer attacks and effects in plantation

6.7.2 Recommended measures to control *Hypsipyla robusta*

- *Hysipyla robusta* damage can be minimized in plantations through the use of integrated pest management strategies.
- Integrated management strategies combine biological control, chemical control and silvicultural control measures to reduce shoot borer invasion in mahogany stands.

6.7.3 Selection of pest resistant planting stock

- Although many mahoganies are attacked by this pest, there are a few genotypes in the sparse populations that are resilient to, or tolerant of the pest.
- These plus trees (mother plants) are selected and multiplied through establishing nurseries of the seeds and vegetative propagation methods.
- The development of vegetative propagation with mahogany genotypes identified as superior offers the possibility of producing pest-resistant or pest-tolerant progeny for reforestation.

Fig. 6.9 Different levels of tolerance of mahogany to *Hypsipyla* attack

6.7.4 Biological control

Biological control involves control of *Hypsipyla robusta* with natural enemies such as insect parasitoids. There do not appear to be many effective natural enemies for biological control programs, including micro-organisms for microbial control. One reason may be that there are not many host specific natural enemies of *Hypsipyla robusta*. However, biological control may be possible with human intervention. Weaver ants are being introduced in mahogany plantations to serve as biological control agent of *H. robusta*.

6.7.5 Partial overhead shading of saplings

Fig.6.10: Biological control with weaver ants

6.7.5 Partial overhead shading of saplings

Shading of mahogany seedlings has been recommended to control *Hypsipyla* activities due to the effects of shade on oviposition and larval development.

- Lateral shade provided by the vegetation may act as physical barriers and as a result adult moths may have limited ability to locate the host.
- Trees planted under shade encourages vertical growth and self-pruning which reduces the number of sites available for attack.
- Shade alters the microclimate which influences populations of natural enemies of *Hypsipyla* spp and adversely affects the larvae.
- *Hypsipyla* attacks are limited by varying degrees of shade that promote height growth of the trees whiles reducing numerous branching.
- It's known that in deep shade (11% canopy openness) the trees height growth is retarded and shoot morphology is altered which reduces larval activities because of the lower nutritional quality that is unsuitable for the shoot borer's growth and survival
- Medium shade level (26% open canopy) that promotes adequate height growth whiles reducing *Hypsipyla* attacks is recommended in mahogany plantations.

Open crown

A

B Medium shade

C Deep shade

Fig. 6.11: A,B,C - Canopy and understorey images of different shade regimes

6.7.6 Chemical control

- The control of pests by spraying insecticides such as DDT, mytasystox, endrin, parathion etc is relatively fast but very expensive and may cause environmental hazards.
- Chemical control of the mahogany shoot borer is only effective at the nursery stage where seedlings are young
- Chemical usage in mature mahogany plantations is rarely done for reasons such as inaccessibility of the larvae, heavy rainfall and high temperatures in the tropics.

6.7.7 Mixed species plantations

Mixed species plantation is one of the silvicultural methods of pest control. Mahogany are planted in companion with *Heritiera utilis, Nauclea didderrichi, Ceiba pentandra, Terminalia* species, *Tectona grandis* and *Entandrophragma* species. Planting of mahogany under a nurse crop provides shading for the saplings at the early stages of growth. Pest incidences in mixed stands are minimized through the following;

- The adult pest may be less able to locate the host trees in mixed species stands than in pure (monoculture) mahogany plantations;
- Shading from the different tree canopies may limit the tree suitability for the larvae.
- It is believed that natural enemies may be more abundant or effective in mixed stands than monoculture.

6.7.8 Other pest and diseases of mahogany

Fig. 6.12: Mixed species plantation

- Seed-boring beetles attack seeds while on the tree and seeds are also eaten by small rodents.
- Logs of mahogany are susceptible to attack by longhorn beetles while sapwood is attacked by the ambrosia beetles.
- Termites can damage mahoganies in nurseries and plantations.
- Fungal disease caused by *Fomesnoxius* (Basidiomycetes) attacks the roots and *Uredo tesoensis* afflicts the leaves.

6.7.8.1 Measures of control

Fig 6.13: African land snail attack *Khaya* seedlings in a nursery

6.7.8.1 Measures of control

- Regular cleaning of plantations.
- Clearing harvested branches from thinning and felling activities from the site.
- Use of species mixtures.
- Removal of attacked trees.
- Promotion of biological control agents.

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7 Silviculture

7.1 Systems/Methods of Planting

7.1.1 Planting system farmers can use

- Mahoganies can be planted in many ways but the most appropriate include monoculture (single species), mixed species and agroforestry.
- The use of any of these systems has its own merits and demerits and so land characteristics and use must be checked before choosing the right planting method for mahoganies.
- Use a monoculture or mixed species method on infertile soil, rocky soil or rocky terrain to improve soil quality and to reduce and/or prevent landslides or erosion.
- Agroforestry systems are more suitable on fertile soil because the benefits from land use can be maximized. The farmer gets agricultural products while expecting timber in the near future from this system.

Fig. 7.1: A high quality Mahogany tree

- Mixed species or agroforestry will increase product diversity in the short and medium term, while providing long-term revenue.

- Choose mixed species or agroforestry systems over monoculture for easy management, increased productivity, economic benefits, and more diversity in the ecological goods and services provided.

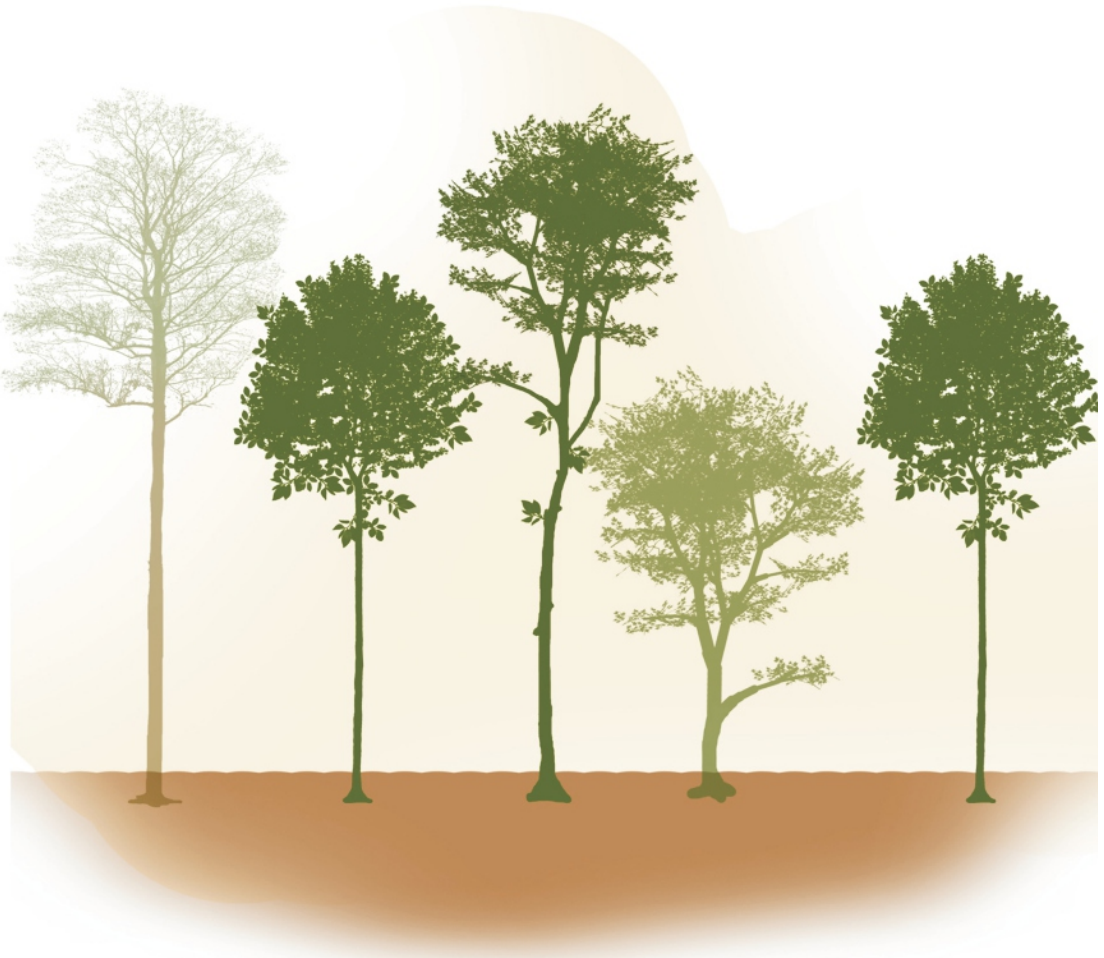


Fig. 7.2: A mixed species plantation

7.2 Mixed plantation system

This system involves planting several different tree species together in a uniform or non-uniform manner on the same piece of land.

7.2.1 Why use a mixed plantation system?

Using this method offers several advantages:

- Increased stand-level productivity, individual-tree growth rates and form, and produce a greater amount of biomass per unit area.
- Better site utilization.
- Diversified production can reduce the market risk associated with single crop systems.
- Mahoganies can be less susceptible to insects (mahogany shoot borer, *Hypsipyla robusta*) or disease problems.
- Mixed stands provide environmental services (soil and water protection and/or rehabilitation, nature conservation, aesthetic benefits and climate change).
- There may be also financial gains from combining fast-growing species that can be harvested earlier in a rotation, with more valuable species that need longer rotations. The first harvest provides an initial cash flow and also improves the growth of the remaining higher value trees.

7.2.2 Mixed plantation systems have some disadvantages:

- Planting mahoganies closely with fast-growing species, such as *Cedrella*, *Eucalyptus* or *Terminalia* species, will cause strong competition for nutrients, moisture and light resulting in slower growth.
- Management of mixed plantations is more intensive and generally

requires more attention to details. For instance, mahoganies are more resistance to *Hysipyla robusta* under shade, but caution must be taken when selecting tree species to be used in combination with mahoganies as excessive shade may result in poor growth.

- Because of differences in production and rotation age, more caution is required when harvesting to prevent damage to surrounding trees.

7.2.3 Which species can be planted with mahoganies?

Species to plant with mahoganies are species that are equally suited to the planting purpose and land conditions.

- Select tree species that are suited to the climate and conditions of the planting site. For example:

  I. In moist areas, *Khaya anthotheca* and *K. ivorensis* intercrop well with many forest trees include *Milicia excelsa, Ceiba pentandra, Terminalia superba, Terminalia ivorensis, Triplochiton scleroxylon, Heritiera utilis* etc.
  II. In the dry zones, *Khaya senegalensis* and *K. grandifoliola* are best combined with species that can grow well in dry areas, such as *Ceiba pentandra, Terminalia superba, Melicra excelsa, Pterocarpus erinaceus* and *Antiaris toxicaria*.
  III. Mahoganies can also combine with fast- growing species, eg *Cedrela odorata*, *Gmelina arborea,* and *Acacia* species, on relatively fertile land.

- Plan the species composition based on production periods and harvest times to diversify the medium- and long-term income. Mahoganies can be planted in combination with one or several tree species with different growth cycles:

  I. Slow-growing species to diversify timber production: Kusia (*Nuclea dedirrichii*)
  II. Fast-growing species to provide medium-term income: Teak, *Eucalyptus and Cedrela*
  III. Species that produce fruits and vegetables to earn monthly or yearly short-term income: orange (*Citrus sinensisi*), mango (*Magnifera indica*), and cocoa (*Theobroma cacao*)

IV. Species that produce fodder and fuel wood: *Leucaena leucocephala*, *Acacia* spp, *and Gliricidia sepium*.
V. Tree species that produce other non-timber products: rubber (*Hevea brasiliensis*).

- The species that can help maintain and improve land and environmental quality include:

I. Species that enrich the soil: Leguminous tress such as *Albizia zygia*.
II. Species with deep roots to prevent erosion.
III. Species that have been observed to maintain cool and moist environment during the dry season e.g. *Ceiba pentandra* and *Spathodea campanulata*. Species that have been observed to reduce Mahogany shoot borer attacks e.g. *Cedrela odorata*.
IV. Avoid species that require a great amount of water: for example pine(*Pinur spp*).

Fig. 7.3: A smallholder Mahogany monoculture plantation

7.3 Agroforestry plantation system

With these systems, farmers plant mahoganies and agricultural or seasonal crops on the same piece of land.

This system can be applied on or around farmland, including paddy fields. The advantage of an agroforestry system is that farmers gain short-term income from agricultural crops such as maize, beans, peanuts, cassava, cocoyam, plantain, and spices, such as ginger and medium- to long-term income from timber.

Mahoganies can also be planted with cash crop in plantations, such as cocoa and oil palm.

7.4 Monoculture plantation system

- This is the most favoured system around the world particularly for industrial plantations.
- This system involves the cultivation of a single tree species. Farmers can plant only mahogany without agricultural crops and/or other tree species.
- Farmers can use this system when they do not have enough labour to manage the land intensively.
- These systems need extensive land, so other jobs or other sources of income are needed to meet household needs.

7.4.1 Advantages and disadvantages of monoculture

The advantages of monocultures are

- The ability to concentrate resources on one species or product.
- Monocultures are simpler to manage and harvest due to their uniformity.

- More timber volume and better, uniform quality timber can be produced from the same area of land.

The disadvantages of planting Mahoganies in monocultures are

- More susceptible to pests and diseases (in the case of mahoganies, more susceptible to mahogany shoot borer, *Hypsiphyla robusta*)
- Less support for biodiversity and low level of product diversification.

7.5 Land preparation

What is involved in preparing the land for planting mahoganies?

- Site selection
- Clearing land of bushes and weed roots
- Stump destruction
- Ploughing
- Harrowing
- Stone removal

7.5.1 Why is land preparation necessary?

Land preparation is necessary to:

- Provide the best growing conditions possible for mahoganies.
- Reduce weeds and improve soil quality.
- Reduce shade, since mahoganies are shade-intolerant species.

7.5.2 How to choose suitable land for mahoganies

Generally all mahoganies grow very well along watercourses. Selecting suitable land for planting mahoganies depends on the mahogany species as each species has its own land preferences.

For example:

- *Khaya anthotheca* grows naturally in:

  - Semi-deciduous areas, in both wetter and drier types.
  - The transitional zone between dry semi-deciduous forest and savanna.
  - Areas with 1500 m altitude, 1200-1800 mm annual rainfall and a dry season of 2-4 months.
  - Fertile deep soils and plenty of water.

- *Khaya grandifolila* grows naturally in:

  - Semi-deciduous areas, especially in drier types
  - Savanna (along watercourses)
  - Areas with 1400 m altitude, 1200-1800 mm annual rainfall and a dry season of 3-5 months.
  - Moist but well-drained soils, and alluvial soils in valleys.

- *Khaya ivorensis* grows naturally in:

  - Evergreen areas but also in moist semi-deciduous areas
  - Areas with 700 m altitude, 1600-2500 mm annual rainfall and a dry season of 2-3 months
  - Alluvial soils which are moist but well-drained
  - Slopes on lateritic soils

- *Khaya senegalensis* grows naturally in:

- Savanna woodland, often in moist localities and along watercourses
- Areas with 1500 m altitude, 650-1300 mm annual rainfall and a dry season of 2-7 months
- Deep and well-drained alluvial soils and termite mounds
- Shallow and rocky soils

7.6 Planting

7.6.1 Activities required before planting?

- Selecting of planting distance/spacing
- Pegging (mapping the location for each seedling to be planted)
- Preparing planting holes

7.6.2 What spacing is right for mahoganies?

- The most commonly used spacings, particularly in a monoculture system, are 1×1 m, 2×2 m, 2.5×2.5 m, 3×3 m and 5x5 m.
- Dense spacing will produce straighter stems and faster height growth, whereas wide spacing will produce larger stem diameters.
- Use dense spacing in the early stages in order to promote height growth, then thinning to promote larger stem diameter.
- In an agroforestry system, just like other tree species, mahoganies can be closely spaced within their rows with a wider distance between rows for planting seasonal crops such as cassava, corn, peanut or soybean.

7.6.3 Why should the planting distance be uniform?

- Makes maintenance easy.
- Makes the best use of space for trees to maximize growth of the canopy, stem and roots.
- Reduces competition between trees for moisture and nutrients from the soil allowing the tree to maximize growth.
- Reduces competition between trees for light and improves air circulation, allowing the stem and canopy to grow healthy.
- Reduces the potential of tree damage due to strong wind.

7.6.4 What is an appropriate size for a planting hole?

- The planting hole is dependent on the size of polypots from which mahoganies seedlings were raised.
- At each peg (made from wood to indicate the location of the planting hole), dig an appropriate planting hole using a digging axe for each seedling.

7.6.5 What is the best way to plant seedlings?

- If the nursery is far from the planting site, seedlings may dry out from exposure or lack of water during travel. In such cases, seedlings should not be planted immediately.
- Maintain seedlings near the planting site for 1 week; this allows them to adapt to the planting environment and recover from desiccation.
- Plant seedlings in the rainy season or when rainfall has made the soil moist.

Before planting, a basic fertilizer of 20g compost (derived from leaves) or manure (derived from cattle waste) should be added to each planting hole. Alternatively, 10 g of NPK (Nitrogen, Phosphorus, Potassium) fertilizer can be applied to each seedling after 2-4 weeks of planting.

When using manure, make sure that the manure used is completely composted and not harmful to the seedlings.

Seedlings can be planted 2–4 weeks after you apply the fertilizer (manual).

- Remove the seedlings from the polybag carefully to keep the medium undamaged.
- Place the seedlings into the planting hole, and backfill it with topsoil or humus. Place soil from the bottom layer to the upper portion of the planting hole.
- Compact the soil by holding the seedling by the stem and gently tamping down the soil around the seedling with your feet.
- Place the seedling bag at the end of the marker, as a sign that the seedling has been planted and to demonstrate that the polybag has been removed.

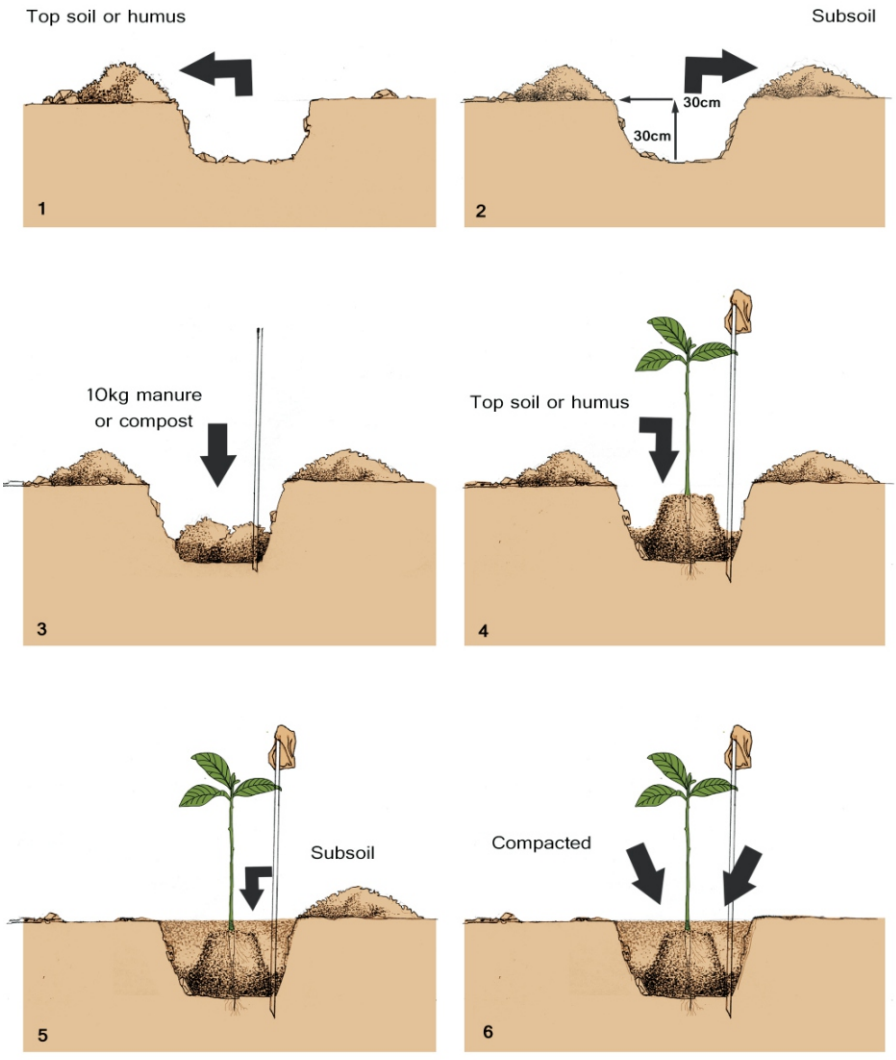


Fig. 7.4: Best method of planting Mahogany seedlings

8 Integrating Mahogany Into Agricultural Landscape

8.1 Why is it necessary to plant mahogany on farm lands?

Mahogany is an endangered species in West Africa due to its demand particularly for timber and medicine.

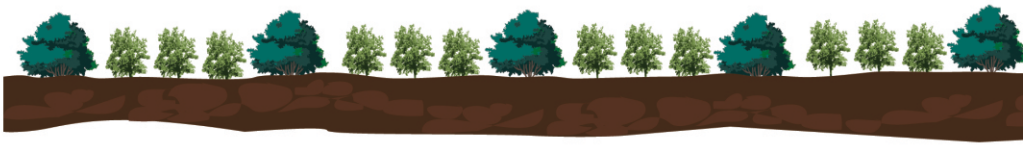
In Ghana mahogany stocks have declined in natural forest stands especially in the off-forest reserve areas on farmlands where the species is needed for timber and various non-timber forest products.
Consequently, its cultivation on farmlands is a priority to supplement production from natural stands and to sustain livelihoods while ensuring environmental conservation.

8.2 How mahogany can be integrated with crops on farmlands?

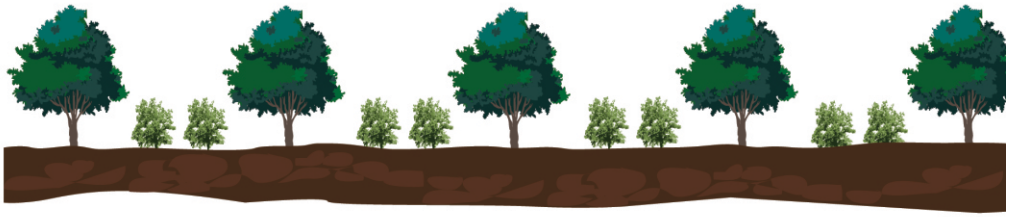
Like many other forest tree species, mahogany can be inter-planted with food crops in the following ways:

8.2.1 Sequential agroforestry system

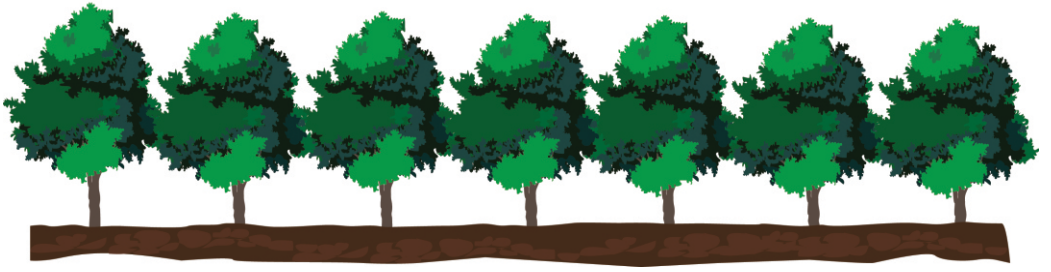
This involves inter-planting food and other crops with trees in the establishment phase or until tree canopy closes (Fig .8.1).



Initial planting of tree seedlings and crops



Years 1-5: Trees grow and begin to shade out crops



Years 6+: Trees close canopy, crops are removed

Fig.8.1: Mahogany trees in a sequential agroforestry system
Source: Adapted from Elevitch & Wilkinson, 2000

8.2.2 Trees with understorey crops

This involves inter-planting trees with crops such as banana, plantain, cocoyam, yam, cocoa, coffee, cashew and other shade loving crops at wider spacing (Fig 8.2).

The tree density is lower to enable the associated crops to remain with the trees for a longer period. This system increases crop diversity and ensures a continuum of products over short, medium to longer terms.

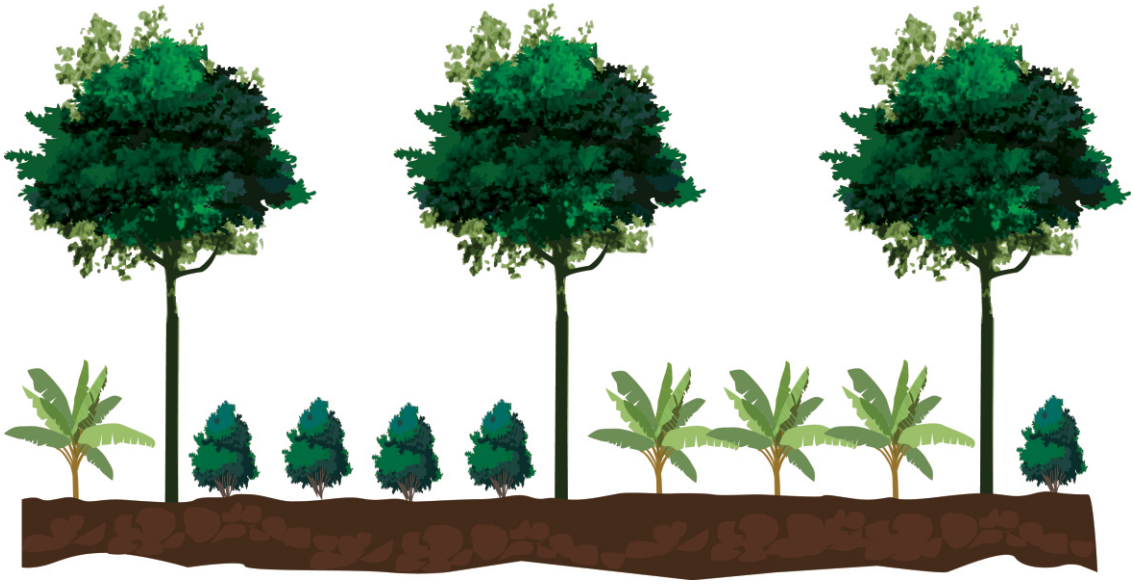


Fig. 8.2: Mahogany trees with under-storey of crops
Source: Adapted from Elevitch & Wilkinson, 2000

8.3 How to involve farmers in planting mahogany on farmlands

One of the most effective ways to engage with farmers to plant mahogany on their farms is through a participatory process (Figure 8.3).

The participatory process begins with introductory meetings to establish rapport with farmer communities between January and February during the off-farming season. During this period, suitable places to work and the people to

work with are also identified.

Preparatory and planning sessions are then held with communities from February to March. The components and design for the most preferred options for integrating mahogany into farmers field are discussed with them for implementation. An open call is made for participation, and interested volunteer farmer/community members are enrolled for planting. The capacity of some community members are built to produce Mahogany seedlings from January-June. Seedlings may also be acquired from other nurseries where available. Seeds of agricultural crops may be supplied to farmers for inter-planting in trees.

Fig. 8.3: Participatory process for integrating mahogany into croplands

8.4 Involving farmers in planting mahogany on farmlands

- Farmers are assisted to peg and plant their fields between May and July (Figure 8.4). They may be supported with cash and other incentives to prepare their fields and supplied with quality mahogany seedlings as well as other materials necessary to enhance the success of their farm forests.

- Monthly monitoring visits are then undertaken after establishment to assess performance of trees planted, especially survival and growth of the trees. Dead tree seedlings are replaced when necessary. The fields may be evaluated at the end of the season or yearly.

- Meetings can be organized with farmers to share problems and review strategies for management of the planted fields. During this period

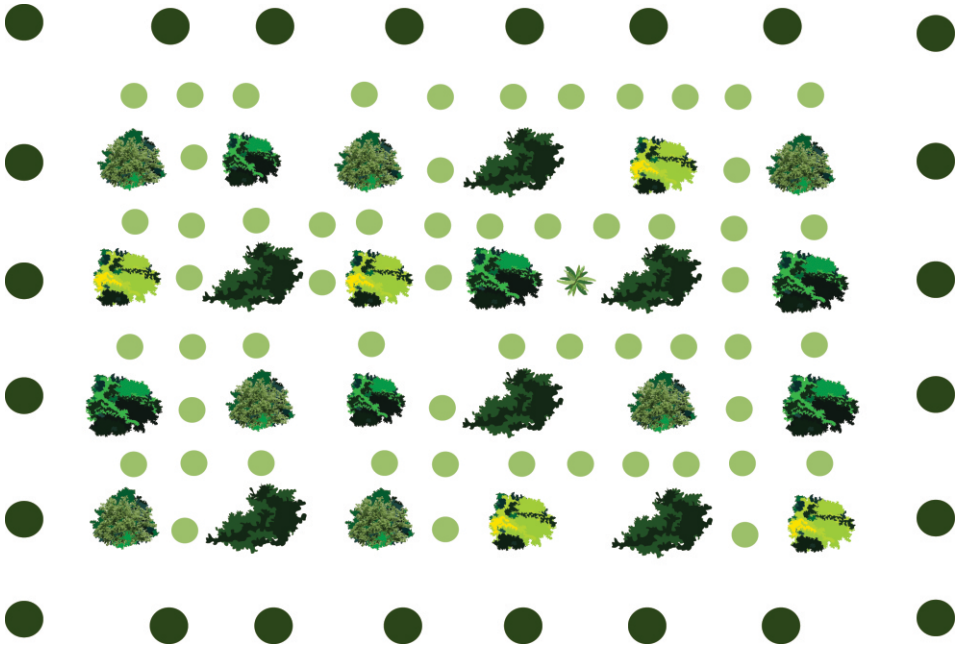


Fig. 8.4: Design of mahogany interplanted with food crops
= Food crop, = *Khaya ivorensis*, = *Khaya anthotheca*,
= *Terminalia ivorensis*, = *Cedrella odorata*

farmers are taught silvicutural techniques including weeding, pruning of branches and managing mahogany shoot borer infested stands and also stands impacted by other damaging agents, to ensure healthy mahogany farms.

8.5 Who should be involved in planting Mahogany on farmlands?

Generally, it has been observed that middle to old aged male landowners are more likely to show interest in planting mahogany on farmlands than women and young male adults.

- Middle to old aged people are more financially stable, property conscious and are resourceful to absorb the risks of diversifying production.

- Most women do not own land and are often occupied with household chores. Thus they have little or no time to participate in introductory and planning meetings prior to planting of mahogany farms.

- In some cases however, where women own land, there is interest in planting mahogany on their farms. Where Taungya System (TS) provided land in degraded forest reserves, women participated to take advantage of access to free land for the production of food intercrops.

- Generally, land tenure restricts the participation in tree planting. Where individuals own their lands, the barest incentives provided facilitated establishment as security is ensured. However, when it involves public or community land, extra efforts and negotiations with chiefs need to be made. Sensitization and provision of adequate incentives to entice planting of mahogany on degraded community lands in agricultural landscapes may be necessary.

8.6 Why do farmers plant Mahogany on their farms?

Farmers are motivated to plant mahogany on their farmlands for tangible and intangible products. The major ones include:

- Timber, medicines, shade, wind protection, soil protection, and soil fertility improvement.
- Legacy to bequeath to their children.

8.7 Is mahogany production on farmlands profitable?

Yes. A preliminary analysis shows that it is profitable to plant mahogany on croplands for at least 25 years to produce timber. Profitability is enhanced when money is borrowed at smaller interest rates up to 10% (Table 8.1).

Table 8.1: Profitability of planting mahogany on individual and taungya lands

Profitability indicators	Value /Ha	
	Nkranka farmlands lands	ABTS Taungya
B/C ratio	10	6.8
NPV (Ghc)	21,184	22359
IRR (%)	25	20

B/C benefit-cost ratio NPV Net present value IRR Internal rate of return

8.8 Challenges in integrating mahogany on farmlands

- Inadequate labour to maintain farm after planting resulting in high competition from weeds.
- Incidence after food crops have been harvested after first 4 years.
- Land tenure often restricts free participation of interested farmers.
- Erratic rainfall pattern and prolonged drought spells delay transplanting of seedlings and may retard tree growth after planting of seedlings.

- *Hypsipyla* attack causing excessive branching and damage at the apex of the main stem on mahogany plants at the sapling stage (Figure 8.5). Consequently, intensive management pruning profuse branches with *Hypsipyla* during the first four years of the mahogany stand is necessary.

Fig. 8.5 Destruction of the apical shoot of mahogany seedlings by *Hypsipyla robusta*

8.9 Important issues to pay attention to when you have mahogany on your farmland

- Many farmers cannot wait until 40 years to harvest timber for sale due to short term household needs. Hence, generation of interim benefits, e.g. honey production, black pepper cultivation etc. is essential, particularly for maintenance of the plantation.

- Economic thinning regimes at appropriate ages during the rotation needs to be determined to produce interim income from thinned wood.

- Farmers must be trained in appropriate thinning and harvesting techniques for fuelwood, medicines, seeds and others, in order not to destroy standing trees in the plantation.

- Frequent monitoring in the initial years of establishment using a farmer-farmer extension strategy may enhance farm plantation success. One of the farmer participants who is experienced and knowledgeable with tree planting and maintenance may be tasked to undertake regular monitoring of planted fields and advise on appropriate silvilcultural practices.

Fig. 8.6: Honey production in a mahogany farm at Kranka

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9 Wood Quality Assessment

9.1 What is wood quality?

- Wood quality is a measure of the appropriateness of wood for a given use.
- It is influenced by many factors which include the density, uniformity of growth rings, fiber length, percent clear bole, proportion of heartwood, percentage of vessels, presence of juvenile and reaction wood and growth rate.
- Different properties of wood impact quality for a particular use such as construction, and may not be same properties for decoration and interior use.
- The quality of the machined wood surfaces influences features such as strength of glue/adhesive and finishing during the manufacturing process.

Fig 9.1: Visual grading of wood

9.2 How is quality of mahogany assessed?

Mahogany wood can be assessed by :

(i) Visual method/grading, eg. Surface quality test
ii. Machine method, eg. Mechanical /Strength test
iii. Field test, eg. Graveyard test

The wood quality of mahogany may vary from one ecological zone to another.

1. Lumber recovery
    - Measure the volume of the log/ tree
    - Measure the volume of each board from the tree or log
    - Use the following formulae

$V_i = H * (S+s)/2$
V_i = Volume of logs in cubic metre
H= length of logs
S= basal sectoral area
s= top sectoral area

Lumber recovery = volume of boards/volume of log *100%

9.3 Wood Durability

- Wood will decay and deteriorate when it is exposed to organisms in the environment.

- Different woods behave differently depending on their nature. Wood quality may be assessed by testing the natural resistance of the mahogany wood to pests, diseases and other agents of degradation.

- Certain other animals do not eat wood but do use it for shelter such as insects (e.g. carpenter ants), birds, rats, and squirrels. Some of these organisms damage wood through the galleries (holes) they make in the wood. Some of the biological agents that attack and the damage they caused are shown in figures 9.4 to 9.7.

- Beside biological agents, wood is destroyed by several other non-biological agents such as chemicals (such as strong acids and alkalis), physical

Fig. 9.2: Processing of harvested mahogany trees

Fig. 9.3: Lumber from Mahogany logs

damage (breakage), mechanical damage (tear and wear of wood in service) and fire.

- Some tree species are more able to withstand the damage caused by destructive agents while others are very prone to their attack. The natural ability of wood to withstand the damage caused by biological agents, especially insects and fungi, is referred to as its natural durability. Natural durability is one of the key performance factors used to assess the suitability of a timber species for a specific application.

- Since all wood is made up of the cellulose, hemicelluloses and lignin, the ability of certain wood species to withstand damage is due to the presence of extractives. However, the sapwood of almost all wood species is classified as nondurable, and hence the natural durability is often assigned to the heartwood of the wood. The durability rating of a species is based on the natural ability of the heartwood of that species to resist decay and insect pests (including termites).

- Chemicals which are toxic to wood destroying organisms occur naturally in some trees. Not all of them contain equally effective preservatives and they do not occur uniformly throughout a tree. Thus, natural durability is a variable property, even among woods with a reputation for it.

- As the tree gets older and larger, storage cells in the center at the bottom of the tree begin to die. Various chemicals are formed from their contents, and additional materials move into the wood. As this part of the tree fills with natural chemicals, its color darkens and become what is referred to as “heartwood''. With further aging, the heartwood core expands outward to the center and upward. Increasing amounts of formerly living and conductive ``sapwood'' are therefore changed into dead and nonconductive heartwood.

- Although all trees develop heartwood, not all heartwood chemicals are the same between species. Trees with more toxic natural chemicals have very durable heartwood. Other trees have only moderately resistant heartwood

and some have no decay or insect resistance at all. In all trees though, even those with very durable heartwood, sapwood has almost no resistance to insects and decay.

- For the heartwood within a tree, durability changes from the center towards the bark. Generally, the center heartwood is less durable than the peripheral heartwood. Dense, dark colored heartwoods are usually more durable than the light, pale colored ones.

- Mahoganies, one of the highly valued, cherished and prized Ghanaian hardwoods, is popular due to its natural figures (for veneer production) and durability. It is rated as moderately durable. The wood has relatively thin or no sapwood of commercial importance. The results from our present study indicated no significance difference between the sapwood and heartwood of this wood species. Plantation timber species are thought to be less durable than the naturally grown or secondary regrowth ones. This is due to the application of silvicultural practices which tend to promote the rapid growth wood and less dense wood. However, the results from our recent work indicated no significant difference between plantation grown and natural grown mahoganies.

Fig.9.4a: Termite attack and damage of wood

Fig.9.4b: Termite attack and damage of wood

Fig. 9.5: Carpenter ant attack and damage

Fig. 9.6: Beetle attack and damage

Fig. 9.7: Fungal attack and damage

9.4 How is durability of wood assessed in the field?

- Prepare uniform dimensions of wood samples (2 x 2 x 20cm).
- Plant the stakes 50cm between rows and 50cm within rows. (Fig 9.8)
- Assess the stakes regularly for the termite and fungal activity on the for a period of 6-12 months.(Fig 8.8)
- Rate the stakes based upon the ASTM D 1758-06 (2008) ratings system.
- Some are highly durable while others are perishable.

Fig. 9.8a: Stakes planted in graveyard test

Fig. 9.8b: Stakes planted in graveyard test

Figure 9.9: Termite attack in graveyard test

9.5 Are there differences between plantation and natural mahogany?

- ·Slight differences exist in the durability of the natural and plantation wood, but those differences are not significant.

- ·Natural appears slightly more durable then the plantation wood (Fig 9.9) in accordance with the AWPA E – 7 – 07 (2008) and ASTM D 1758 – 06 (2008).

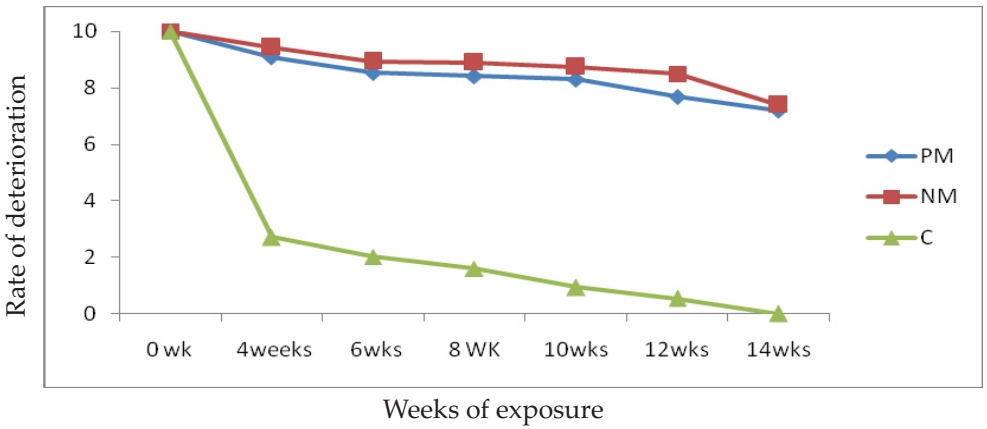

Figure 9.10: Rate of deterioration in natural and plantation mahogany samples

9.6 Wood strength quality

- Wood to be used for construction purposes should be tested for various strength properties.
- Some of the properties are tensile, shear, bending, compression and hardness.
- These strength tests can be conducted in the laboratory on small clear samples or structural sizes.

Fig. 9.11: Wood sample for mechanical test

Fig.9.12: Testing of mechanical strength properties

9.7 Surface Quality Assessment

- The quality of machined surfaces influence manufacturing processes such as strength of adhesive and finishing.
- Generally, surface quality assessment is done by visual observation that is subjective and qualitative.
- There are non-contact techniques, which assess the surface profile.
- Examples of non-contact techniques are optical profilometers, microscopes, image analyzers, imaging spectrographs, interferometers, fiber-optic transducers, laser scatters, and optical light-sectioning systems.
- The contact process of measuring surface roughness like the stylus profilometer provides a more quantitative and hence more objective measure of the surface profile.
- Stylus profilometer and optimal deflectometry techniques are some examples of more objective methods.
- The deflectomery device give texture values of the surfaces at different wavelengths.

Fig.9.13: Sanded mahogany samples

Fig.9.14: Optimap device for texture

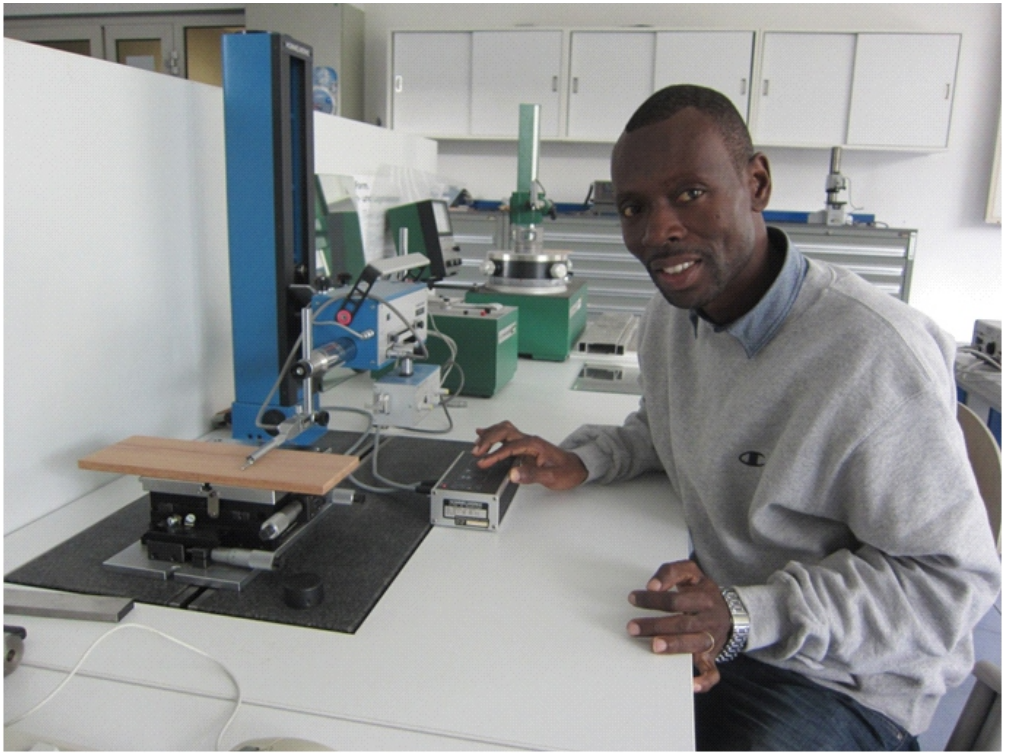

Fig.9.15: Stylus device for roughness test of mahogany samples

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10 Summary of Recommendations

The field guide "Managing Mahogany Plantations in the Tropics: Field Guide for Farmers" contains details about the background and implementation of recommendations relating to growing mahogany in plantations. The purpose of this summary is to provide the key findings that are presented in the book.

1. Obtain the best seeds that are available. Seeds from seed orchards are preferred, but if not available, seeds can be obtained from certified seed production areas or from the best trees in the local area. The timing of fruit collection is important to ensure that the seeds are mature.

2. Plant seeds in a light, well-drained soil at a depth that is as deep as the seed diameter. Spacing of seeds, transplanting of seedlings, application of fertilizer, weeding and watering are all essential components of growing high quality seedlings.

3. As an alternative to seeds, cuttings from superior mother trees can be rooted. This requires more specialized growing environments and close attention to the humidity in which the cuttings are kept.

4. Seedlings and rooted cuttings should be planted out on land that has been suitably prepared to provide the best growing conditions. Spacing and method of planting are important.

5. The main concern once seedlings are planted out is damage from the mahogany shoot borer. This insect tunnels in the shoots of young trees, causing their growth form to be forked. A number of recommendations can be made to reduce damage by this insect.
   a. Plant resistant or tolerant stock if available.
   b. Encourage populations of natural enemies of the shoot borer, such as weaver

ants.

c. Grow plantations under partial canopy shade. This has been shown to reduce damage to young trees.

d. Establish mixed species plantations. This reduces the chance of pests or diseases eliminating large numbers of trees and enhances habitat for biological control agents. The mixed species may include cash crops such as cocoa and oil palm.

e. Prune out damaged shoots and destroy them. This helps trees to recover and enables a new terminal shoot to develop.

6. In addition to considering ways to reduce damage by mahogany shoot borer, regular plantation management activities are necessary. These include weeding, fertilizing, pruning, thinning to remove poor form or diseased trees, and beating up (replacement of dead plants).

7. Mahoganies can be planted in agricultural landscapes in collaboration with farmers. These provide a number of benefits, including tree products, wind and soil protection and a legacy for future generations.

8. Differences in wood quality between natural and plantation grown mahoganies are not significant.

This book was produced to meet the needs of farmers and practitioners for a practical guide about establishing and managing mahogany plantations. It is divided into ten chapters on Silviculture, maintenance of mahogany stands, seed and seedling production, description of different mahogany species, wood quality assessment and how to inegrate mahogany into agricultural landscape. Techniques presented in this guide are drawn from many sources: the available literature; personal communications with experts and results of field experiments in different ecological zones in Ghana. That general information is complemented with lessons learned from other activities of this project. We expect that the book will be useful not only for farmers at the project sites but also for any smallholders growing mahogany, policy makers, researchers, extension officers, and organizations involved in mahogany plantation establishment.

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