Urban Planning, Sanitation and Beautification

Urban Nursery Management
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PART ONE

BACKGROUND

1.1. Introduction

Forests, trees and shrubs are vitally important to urban people. They provide many products, including food for humans and animals, timber, fuel and medicines. They not only provide products, also protect the environment and improve the living conditions around a farm and urban areas. For example, they provide shade and shelter and play a vital role in preventing soil erosion and in sustaining soil fertility. Thus, proper management of trees and forests is necessary to increase greenery and make resources sustainable. As urbanization increases, it is really very important to increase greenery. Trees and shrubs as well as other plants in urban areas can be used in a variety of ways; they can be planted in various locations and for many purposes. They are extremely valuable in shaping the landscape and in sustaining the capacity of the land to support a growing population.

The environmental impacts of urban growth on communities are receiving unparalleled attention in current international debates on development. To accommodate the increasing needs of urban population, agricultural lands are being converted into residential blocks and spaces for urban infrastructure. This has resulted in five major consequences: loss of productive lands, traffic congestion and air pollution, underground hydrological modification, change in consumption habits and affordability in accessing food for low-income urban residents. In this context, urban greening is increasingly acknowledged as a development tool.

1.2. Rationale of the Manual

Urban greening has different Green Infrastructures (GI) that in general provide sustainable regenerative solutions for the urban challenges. Green Infrastructures can be established and managed for provision ecosystem goods and services to society. They increase the resilience of ecosystems
inter alia - by improving their functional and spatial connectivity by increasing ecological coherence and improving landscape permeability (Naumann et al. 2011). Currently their contribution to climate change mitigation and adaptation and to minimize natural disaster risks, such as floods, forest fires, avalanches and droughts is well recognized. This contribution could only possible if right type of tree, shrubs and other plant species are selected and managed from seed collection to out planting time.

Enhancing understanding and developing skills of practitioners on seed collection and handling, compost making, nursery site establishment and seedling handling up to out planting are critical in sustainable urban green infrastructure management. The urban nursery can hold young trees from 3 months to 2-5 years. Any wrong doing at this stage of development could lead to unwanted or unwise UGI. So, in order to produce healthy and vigorous seedlings for greenery and different plantation programs, knowledge about forest seeds particularly, their biology of development, seed collection methods and techniques, handling procedures, extraction and seed testing is really very important. Because, seeds have been an important tools for development in the reproduction and spread of flowering plants, relative to more primitive plants like mosses and ferns. Additionally, changing seeds to seedling and then field planting value is interesting point. Therefore, it is so important to enhance skill of practitioner and land managers either through training or provision of manual on nursery establishment and seedling production and handling.

1.3. Objectives of the Manual

1.3.1. General

The overall objective of this manual is to provide support to urban development organizations that wish to strengthen their present activities particularly in urban nursery management practice (seed collection and handling, propagation and seedling production) and greening development that contribute to CRGE.

1.3.2. Specific

a) develop skills of practitioners on mother tree or plants selection, seed collection, seeds handling, seed processing, seed testing and long term storage of seed;

b) strengthen skills practitioners on nursery soil preparation and other nursery operations;
c) develop skill on the basic components that urban nursery, practice such as lay outing and constructing the components of urban nursery;

d) offer skill and knowledge required to establish urban nursery and produce planting materials for urban tree planting endeavor;

1.4. Expected Results

a) Final implementation manual with explanatory texts for each green infrastructure component developed;

b) Provision of training on the implementation manual for at least 30 stakeholders.

1.5. How to Use the Manual

The manual provides general information on urban nursery management practice particularly on compost, seed collection and handling, propagation and seedling production for urban greening. This manual is not complete by itself and appropriate for individual species. Other detailed monograph or special manual might be needed.

1.6. Scope of Application of the Manual

During preparation of this manual different approaches were followed. In the first step, a survey was conducted in 36 urban centers at three agroecology across the country. The outcome of the survey was as core material manual. Experience from horticultural and forestry nurseries were included in the manual. Literature review nursery management practices was another approach followed.

In the first section of this manual book review, the theoretical backgrounds of vegetative tree propagation, types and function of plant hormones, tree domestication are discussed. In the second section important facilities to carry out the vegetative propagation are presented. In the last section, the types, principles and guidelines for specific vegetative agroforestry tree propagation techniques are dealt. Particularly, cuttings, grafting, layering and so on are discussed. Additional pictures from different websites have been incorporated in the book review to make it more informative.
With the completion of this manual it is hoped that field practitioners will now have access to information or techniques that help them to work in different agricultural different. We hope that the this manual will prove useful to all practitioners in their vital work of helping the producers/land managers and individual household who manage horticultural and field crops as well as livestock. The manual is not complete by itself. Based on the information available in this manual, detailed manual for individual species of subsector has to be prepared of specific situation. The manual is developed to be used in all agroecologies and organized in four main parts. Part one deals with horticultural crops production and protection technologies. This was followed by part two which deals with field crops production and protection technologies. Part three focus on livestock production and protection. The final part deals with mainly pre-urban agroforestry practices/technologies.
PART TWO

STRUCTURE OF THE MANUAL

2.1. Seed collection and Handling Techniques

2.1.1. Seed collection

A. Planning for seed collection

It is important that careful planning precedes seed collection and all the processes that follow. Since planning relates to future activities, it not only requires knowledge of the biological basis, but also of succeeding activities like collection, processing, storage and germination. Planning of seed collection relates directly to find answers for the following questions:

a) Which species to collect (species selection)
b) How much seeds to collect (quantity)
c) Where to collect (seed sources, seed trees)
d) When to collect (harvest time)
e) How to collect (collection method)

The tree planting objective determines the first two questions, which is normally beyond the decision of the seed supplier. The planner must often be able to predict future demand... To compensate for annual fluctuations in seed production and seed demand it is usually sensible to establish a reserve stock of seed in a seed store. The last three questions are related to the immediate objective of seed collection and to provide the appropriate quantity of seed of a particular species and provenance with high physiological and genetic quality at the lowest possible cost.

Species bearing easily collectable, abundant and regular crops, which remain on the tree for a long time with little loss to predation and dispersal, impose little problem in collection but are unfortunately few. Several species produce small crops during a prolonged season but, little can be harvested at any one time. Others have abundant seed crops only at long intervals and in some species the seeds are dispersed or destroyed by predators.
Planning of collection data involves prediction of these ‘where’, ‘when’, and ‘how’, which are based on knowledge of the biology of the species and current observations.

1) Why – defining the purpose and use of the seed collection for business, horticulture, forestry, restoration, conservation

2) What – defining high quality seed collections (a) correct target species identification and verification, (b) healthy, sound, viable seed, (c) sufficient sized collection to meet the intended uses, (d) genetically representative of the species, or population sampled, (e) adequate associated data to meet intended uses

3) Where – being at the right place like species distribution, local abundance, provenance and accessibility

4) When – at the right time which depend on plant type, fruit type, climate, elevation, micro-habitats etc.

5) How – making high quality collections which depends on impact and ethics, sampling methods and techniques, collection methods and post harvest care of collections

Additionally, prediction of quantity and quality of an expected seed crop and prediction of the correct harvest time is especially essential for species with variable seed crops from year to year, and with a short harvest season. Some years, fruit production may be slow that collection does not pay at all; others years a sudden mast production. The best seeds are produced in mast years, or in stands with prolific flowering and efficient pollination and few predators. The best time to collect seeds is when they are mature but before they are also lost to predators or dispersal.

B. Seed collection methods and techniques

a) Pre-conditions for seed collection:-

Once you have identified the parent plant or tree with the right species, provenance and undertaken flower and seed surveying, the next step is collection of seeds or fruits. But still you need to see things like:

Organizing collection teams: The number of teams to be formed depends on the scale (large, small) & purpose (Research, developmental) of collection. Each team should however be composed of a Climber, ground assistants (1 or 2), and a supervisor. The need for training should also be considered at this stage.

Organizing equipment and transport: Ladders, climbing and safety equipment, safety belts and ropes, helmets, climbing spurs, shears, hooks canvas, nets, binoculars, pruning saws etc.
Organizing permits: in some cases you might require permit to collect seed from conservation sites, botanical gardens, forest plantations etc.

Organizing record keeping: Basic information data to include: collector name, date of collection, species, location (locality, distance, latitude and longitude), site characteristics, tree and stand characteristics, collection methods, amount... signature!

1) Factors influencing choice of collection method:-
The seed collectors must know and familiarize with the factors which may face at the time of seed collection.

i. Climate and weather Conditions during collection:-
Dry weather conditions are usually the most ideal for seed collection: movement within the seed sources is easier because of the dry ground with reduced risk of vehicles getting stuck and because of more open vegetation Collection form the ground may be possible during the dry season but impossible during rain. Moist or wet weather is generally not suited for seed collection. Accessibility and movement may be hampered, camping difficult or unpleasant. Ground collection may later be hampered by growth of ground vegetation muddy ground or early germination of fallen seeds. Collection by shaking is usually more difficult in moist weather is both more difficult and more risky: bark gets or lichens. Humid condition also impedes drying and extraction of dry seeds in the field. High air humidity may in certain condition be beneficial for collection of dry fruit and cones since seed are less likely to be lost when the fruit or cones are moist. Windy conditions hinder almost all type of collection. Generally, the danger of falling branches or heavy fruits during strong wind makes any stay in the forest risky.

ii. Damage to trees:-
Collection form standing trees involving climbing by the aid of spurs and pruning of seed bearing branches will inevitably cause some damage, but on a moderate scale it rarely influences general health or future seed production. In some cases, insects or diseases may use scars as entry points for attacks. Both damage and the ability to close wounds depend on species. But, species with thick bark (e.g. Cordia africana) are little prone to damage whilst species with thin bark and less resin are more easily damaged. Susceptibility or resistance to damage of individual species should be considered in connection with choice of collection method.
iii. Accessibility and terrain:

Apart from managed seed sources, which have normally been established with a view of accessibility during seed collection, many seed sources are isolated and scarcely provided with roads. Equipment must be carried. Heavy and bulky equipment like ladders must often be left behind during expeditions far from roads and in hilly terrain. This transportation would be costly for

iv. Shape and height of seed trees:

Crowns of shorter trees may be reached by extended pruners or saws, or saws, or flexible saws or other equipment operated from the ground or the top of vehicles. Trees with long relatively straight clear boles of relatively small diameter can be climbed, up to the crown, by the help of spurs or a tree bicycle. Trees with large diameters, trees with large buttresses and overgrown by vines, climbers, stranglers or other large epiphytes, are very difficult to climb with spurs and a tree bicycle cannot be used. Here ladders, advanced lines or shooting are usually the only solutions. Large spreading umbrella-shaped crowns typical of many Acacia and Albizia species make the use of safety equipment very difficult and climbing of these trees may be excluded altogether.

v. Type of fruit and seed:

Small seeds from dehiscent fruits like eucalypts, casuarinas, conifers and other horticultural fruit trees must be collected by picking the fruits from the tree before the fruits open. Pre-mature collection always involves direct harvest from the tree. Large conspicuous seeds may be collected from the ground. However, those collected under the trees are often seeds that failed to be dispersed which may be only a fraction of the actual fruit production. It may suffice for small collections but usually not for bulk collections.

vi. Special tree problems:

In some species climbing within the crown can be subject to specific problems. Many dry zone species especially from Africa are extremely thorny and spiky and on e.g. Acacia polyacantha and many Erythrina spp. Large thorns occur on the stems and main limbs. Albizia, Parasineranthes, Pterocarpus and many other Leguminoseae plus several Cordia spp. are often inhabited by extremely aggressive ants, which readily attack climbers. Tree crowns inhabited by
wasps or bees may also present a real danger. Therefore, it is advisable to examine the crowns with a pair of binoculars before climbing: if there are wasps or bees’ nests, the trees should not be climbed.

vii. Identity of mother tree:-

In tree breeding the identity of the mother trees often has to be known and this inevitably requires that collection is carried out directly from the parent tree and not from the ground, unless distance to other trees excludes alternative maternity. Collection from spread out tarpaulins after shaking individual branches of the mother tree in question may be applicable. However, the released seeds may be contaminated with seeds from neighboring trees, e.g. if the branches of the canopy are somewhat entangled. Care should also be taken when collecting seeds directly from the crowns of trees with interlocked branches, as it can sometimes be difficult to see which branches belong to which tree.

viii. Future seed crop:-

Damage to trees caused by cutting off branches may indirectly influence future seed crop by reducing the number of potential fruit bearing branches. Pruning may be directly detrimental to the next crop if young undeveloped fruits are removed together with mature fruits. This is a potential risk when fruit development takes more than one year, typical for most conifers. However, moderate pruning may have a beneficial effect on future seed production as it promotes exposure to light of the remaining branches.

ix. Efficiency and labour costs:-

The easier and quicker the seeds can be collected, the lower is the collection cost. Collection form a heavily overloaded tree is obviously more efficient than collection of the same amount of seed from several different parents. Any method involving climbing is likely to be fairly time consuming. Hence, once the climber has reached the crowns, he should collect as much seed as possible. Further processing costs should be considered in connection with choice of collection method. Collection methods in which much debris like soil particles, stalks or leaflets are mixed with the seed may make cleaning or other processing difficult.

Refer part VI number 3(b-d),UGIS 2015

2) Techniques of seed collection
### i. Collection from the ground

- **Collection after natural seed fall:**

  Applicable for Species with large indehiscent fruits or large seeds
  Mainly appropriate for species with short duration of fruit maturation.
  Method wait until most fruits and seeds have matured and fallen to the ground.
  Large or dense ground vegetation and debris must be removed a couple of weeks before seeds fall
  The fruits or seeds are simply picked up by hand or possibly by the aid of a pair of large pincers.
  If there is a large amount of fruit or seeds and the ground relatively free for debris, the fruit may be raked together.

In seed orchards on flat terrain and with short ground vegetation natural fallen seeds may be collected by mechanical equipment using vacuum (light seeds) or rotating brushes (heavier seeds) or collected form spread out ground covers.
Figure 1: Seed collection from the ground

- **Collection after shaking**: Applicable for relatively low trees with dehiscent large-seeded fruit or indehiscent mature fruits that easily separate from the branches; e.g. fleshy fruit and samaras.

Fruit-bearing branches can be shaken from the ground by the aid of a hook mounted on a long thin pole. Many conifers may be shaken by placing the line over high branches and then pulling the ends of the rope to one side and shaking sideways.

Shaking is an operation of short duration it is usually feasible to place tarpaulins or sheet under the trees before shaking to ease collection of the fallen fruits and seeds.

Special powerful mechanical tree shakers have been constructed for use in intensive seed collection form seed orchards or other high-producing seed sources on flat terrain.
• Collection from the crowns of felled trees:-
Applicable for mainly bulk collection, collection can be combined with logging operation. Individual trees with good phenotypes preferably marked as seed trees before logging. Fruits are harvested from the crowns as quickly as possible after cutting. Large fruits are picked individually; small fruits are collected from cut-off fruit bearing branches. For small fruits it may be an advantage to release the fruit by pulling the branchlets through a stationary rake device.

• Collection by climbing tree:-
Climbing has to be used when trees are tall and the fruit or fruit-bearing branches cannot be reached tools from the ground. This applies to the some fruit and seed types and the same fruting behavior as those collected from the crown with access form the ground (small fruits/seeds, heavy and early predation or dispersal, delayed abscission etc.). Climbing is difficult, time consuming and implies (even with the best safety measure) a certain risk, and is used only where there is no other alternative, with is in fact quite common, especially for bulk collection of large plantation.

Native forest dwellers are often extremely good climbers and able to climb tall trees bare-footed sometimes with the aid of a short rope tied between the feet. The methods are strenuous and potentially dangerous. In forest seeds collection safety should have high priority and climbing only be under taken by trained climbers using appropriate safety measures. This always includes the use of safety belts or harness connected to a safety line or safety strop. Efficiency in climbing depends on the tree form, the climbing technique, the seed crop, and the climber.
Selection makes sense because the young trees will be expected to inherit the favorable characteristics from the mother tree, such as fast growth, upright or spreading shape of the tree crown, good flowering and fruiting and tolerance of diseases or pests (Verheij, 2004).

- **General comments concerning seed collection:-**
  
  Seed collected directly from trees is of high quality. Selection makes sense because the young trees will be expected to inherit the favorable characteristics from the mother tree, such as fast growth, upright or spreading shape of the tree crown, good flowering and fruiting and tolerance of diseases or pests (Verheij, 2004). During field activities, seed that has been collected should be placed in a temporary storage. Seed lots should be labeled before initial processing. Place sacks or containers of seed in a dry and cool room with good air circulation.

**ii. Post-harvest procedures of Fruits and Seeds**

- **Seed handling after collection:-**
Newly collected fruits and seeds are particularly susceptible to damage, primarily because they often have relatively high moisture content. Since loss and deterioration of seeds are irreversible, appropriate handing immediately after collection is crucial for the ultimate seeds quality. Therefore, the activities like reduction of bulk, maintaining viability, maintaining identity, keeping seed lots from foreign materials are the major activities which must follow after seed collection.

- **Reduction of bulks:**
  Generally, twigs, leaves and other debris are at the best, redundant materials to transport and store at the worst they are potentially detrimental to seed viability as they contain moisture and possibly seed pathogens. Whatever non-seed material can be easily removed should be removed both to reduce bulk and the potential risk of seed damages. However in small fruited species like eucalypts a moderate amount of twig material is usually kept with the fruit at this stage as it increase the air space between the fruits and hence improves aeration.

- **Maintaining viability:**
  High moisture content creates an ideal for fungi and bacteria. Moist seeds and fruit respire, which create heat and consume oxygen. If the oxygen is depleted because of inadequate aeration, fermentation replaces respiration. This high temperature coupled with high moisture tends to accentuate respiration or fermentation, the prices can be self-accelerating, resulting in combustion of the whole fruit or seed lot. Therefore, maintaining the viability is very important: (a) during any prolonged storage in the field proper ventilation should be assured and the moisture content reduced as much as possible (for orthodox seeds), (b) reduce the transit period as much as possible, (c) if germination cannot be avoided, to keep the germinated seeds in a stage where they cannot be delivered directly to the nursery. Generally- avoid overheating; don’t expose to direct sun light; excessive drying should be avoided; reduce transit period if germination can’t be avoided.
• **Maintaining identity:**
  Collected fruits and seeds loaded and unloaded several times during seed handling are prone to mixed up and lose their labels and identity; therefore to minimize the risk; observe the caution; seed lots should be labeled (identical labels placed inside and outside i.e., as insurance against accidental lose); labels should be water proof; Labels should be includes minimum information recorded like species, seed lot no, geographic location, name of seed source, wt. of seed contained, date of collection, collector’s name, etc.

![Image of labeled seed lot]

Figure 3: Labeling of seed lots

3) **Hygiene and contamination:**
Keep seed lots from foreign seeds or microorganisms, contamination occur seeds stored in the same containers like in unclean/contaminated. If seed lot accidentally blow, split or mixed with others. Therefore, small seed can be removed e.g. dry or wet brushing, bags should be turned inside out when clean, containers and trays should be free from holes or damage.

4) **Condition during transport:**
General guidelines of how to transport seed: Assure optimum ventilation for orthodox seeds; Protect seeds from moisture by covering with tarpaulin/sheet or other water proof materials; Avoid parking transport vehicle directly in the sun; Avoid desiccation of recalcitrant seeds; Protect cold sensitive seeds like recalcitrant lowland rainforest seed if the road has to pass high altitude areas; Transport of sacks placed in cardboard boxes helps to insulate and protect the sacks and contents Seed processing Seed or fruit processing has an objective to
achieve clean, pure seeds of high physiological quality (germinability) which can be stored and easily handled during succeeding processes, such as pretreatment, transport and sowing. Procedures involved under processing of fruit or seeds are:

i. **Pre-cleaning:**
Pre-cleaning can be done for fruit or seed lots containing larger debris, leaves, twigs, empty fruit parts. In the field it is done to reduce bulk during transportation and storage. They should be removed because they can carry fungus spores, invite insects. Pre-cleaning facilitates efficient use of processing equipment and hence efficient extraction and subsequent cleaning. Pre-cleaning for smaller quantity seed lot is usually done manually after arrival at the seed processing depot. Large quantities of fruits are pre-cleaned mechanically (e.g. vibrating or oscillating screens or in tumbler)

ii. **Pre-curing:-**
For fruits that must be after-ripened, or where rapid desiccation hampers extraction. It is the deliberate storage and slow air drying of fruits and contained seeds in order to render them more suitable for subsequent operation of kiln drying, extraction and long term storage. Pre-curing of fleshy fruits should always be carried out while the fruits are spread. Procedures for pre-curing include: separate fruits into two or three maturity classes; store at ambient temperature; reduce moisture as the fruits approach mature colour; conclude the process as the fruits attain mature colour.

iii. **Extraction:**
Simply, it is the separation of fruits from seeds. This is necessary to: reduce weight and volume; enable more rapid drying; for storage under low risk of fungal attack; eliminate the negative impact of fruit chemistry on germination. Methods of seed extraction are like de-pulping (fruits such as Podocarpus, Olea, Azadirachta, Melea, Prunus, Juniperus), under cover drying (for species that cannot withstand direct sun light), Sun drying used for species that can withstand high temperature (e.g. many dry land species) and artificial drying (kiln drying)

Dewinging, for fruits and seeds with wings. Also including removal of dry appendices like spines, arils and hairs. It is done manually or by machine (cement mixer, mechanical de-winger),
by tumbling, or threshing. Cleaning for fruits or seeds with impurities like fruit parts, leaves, twigs, empty seeds, foreign seeds and chaffs. Grading for seed lots with large variation in seed size or weight. Adjustment of moisture content: for seeds which after the procedures, a higher or lower moisture content.

Normally seed processing normally follows these orders, but certain steps may be irrelevant and hence omitted for particular species or seed lots. Processing implies a risk of losing seeds both by under treatment (insufficient extraction of seeds) and over treatment (that may damage seeds with consequent loss of viability or reduced stability). Processing should be as far as possible, take place immediately after the fruits or seeds have been brought to the processing depot. The timely order of processing should give high priority to species and seed lots with easily deteriorating seeds (fleshy fruits & recalcitrant seeds)

C . Seed storage

Seeds are kept under conditions that maintain viability at reduced physiological activity, and protecting seeds from deterioration by fungi and insect attack. Factors affecting the viability of stored seeds are moisture content, seed maturity, initial viability, fungi, bacteria, insect, temperature and Oxygen

a) Storing Orthodox Seeds

Seeds of species that can be dried to moisture content of approximately 5% and can be stored at a low or freezing temperature for a long time are described as Orthodox. Example: Most Acacia sp., Albizia sp., Eucalyptus sp., Combretum aculeatum, Commifora africana, Entada africana, Erythrina abyssinica, Hygenia abyssinica, Cordia fricana, Phoenix reclinata, Tamarindus indica etc. Many tropical legumes can be stored for many years without losing much of their viability even at room temperature supposing their moisture content has been reduced to 5-8%. For long term storage (e.g., gene conservation), temperature can go as low as -18 °C but care should be taken that water does not crystallize within the cell.

For orthodox seeds: at room temperature (20-25 °C), ambient moisture content, storage possible for several years (Acacia, Prosopis spp.). However, long term storage, use appropriate facilities like refrigerators, deep freezers, Storage containers.
b) Storing Recalcitrant Seeds

Seeds that cannot survive being dried below relatively high moisture content (often 20-25 %) and may not subsequently be stored for long periods without losing their viability are described as Recalcitrant. Example: Pouteria (Anningeria) adolfi-frederici, Ficus sycomorus, Syzygium guineense, Tamarix aphylla, Warburgia ugandensis, Ximenia americana, Azadirachta indica, Hevea brasiliensis, Prunus. These are the kind of seeds posing problems for the seed man; do not withstand appreciable drying and requiring different processing and storage.

D. Seed testing

Seed testing is analysing of some physical parameters and physiological quality of seed lot, based on small representative. Quality in this context is about physiological in contrast to genetic quality: Is measure of potential performance of a seed lot under optimal condition; Determines efficiency of raising plants in nursery & subsequent operation. Seed testing is the cornerstone of all other seed technologies. It is the means by which we measure the viability and all the physical factors that regulate the use and maintenance of seeds. Everything that is done with seeds should have some test information to guide the work and ensure high quality. Seed tests tell if a crop of seeds is worth collecting, if handling procedures are correct, and how many potential seedlings are available for regeneration.

The earliest form of seed analysis, the cut test, is still often used today. Before seeds are collected in the field, some seeds are cut open with a knife or razor blade to see if their internal tissues are fully developed and undamaged. This analysis is made more accurate in some cases by the use of a hand lens. It is also used for simple analysis during extraction and cleaning, or after germination to determine if the ungerminated seeds have deteriorated or remained dormant. Although the cut test is often very good at producing some information quickly, it is limited in the amount of information it can supply and it lacks accuracy compared to more sophisticated procedures. Therefore, it should never be taken as a substitute for a formal laboratory analysis.

Standard parameters such as seed weight, purity, and germination or viability enter as factors in the calculation of seed demand. Quality tests may be carried out at intervals from harvest until the seeds leave storage to be dispatched or sown in the nursery (Schmidt, 2000).

a) Sampling
Different seed tests are based on samples, and the sample should be representative. To get a representative sample, first mix the seed lot thoroughly (if it’s a small lot) or take a certain portion of the seed lot, mix it thoroughly and make a ‘composite’ sample. Sampling can be done by: halving, random cup method, using mechanical seed dividers (sampling and mixing). However, sample size depends on seed size: if there are < 5 seeds per gram, a minimum sample of 500 g is needed; on the other hand, where there are more than 750 seeds/ g, a minimum sample will be 3 gram.

b) Geniuses test (true- to -type)
Examine the seeds whether they conform to the species on the seed lot label or not. It is helpful to keep a reference collection of seeds as a check. With small seeds, we may also need hand lenses/ stereo microscopes.

c) weight determination
Weight considered as quality aspect for many species (larger, heavier seeds have higher germination rate, more vigorous) Sample of pure seed separated for weight determination during purity testing; It can be expressed as weight of 1000 seeds or number of seeds per g/kg, International Seed Test Agency (ISTA) recommends 8 samples to be used in wt determination.

d) Moisture Content of seeds
Seeds should have appropriate moisture content for storage or transportation. Their MC s/d have periodically This involves even drying (at 105°C for hours) a weighed amount of seeds determining the MC % on a wet-weight or dry weight basis. This involves even drying (at 105°C for hours) a weighed amount of seeds determining the moisture content % on a wet-weight or dry weight basis:

\[ \text{MC} \% (\text{wt-wt basis}) = \frac{W-W_0}{W} \times 100\% \]

\[ \text{MC} \% (\text{oven dry wt basis}) = \frac{W-W_0}{W_0} \times 100\% \]

Where; W- original or fresh wt
W_0- oven-dried wt of sample
e) Purity testing

The procedure include: have the samples of seed lots at lab; take the weight of the samples (N); Separate pure seeds from inert matters like broken seeds, undersized, shriveled, damaged seeds; Take the weight of pure seeds (n); Calculate purity percentage (divide n/N*100), & then determine the purity of your seed lots.

f) Germinability test

Procedures: Have forest seeds (if) and then mix together in order to have composite samples[ Take some portion from your seed sample; Prepare the filter paper and petridishes (if possible sterilize them); Put the filter paper on petridishes; Put your sample on already prepared petridishes (have at least 3 replications); Water your seeds soon after you put it on petridishes; Follow up for 7 consecutive days and assess the seed germination; Judge whether the seeds are dormant or not; Compute some germination parameters like germination percentage, germination energy and germination value

g) Dormancy

Seed dormancy refers to the state in which viable seeds fail to germinate when provided with conditions normal to germination, i.e. adequate moisture, appropriate temperature regimes and normal atmosphere (Bewely and Black, 1982, 1994; Schmidt, 2000; Gu et al., 2003). Seeds of most tree species have been found to be dormant and therefore do not germinate readily with some of them taking several months to germinate (Tahir, et al., 2007). After carrying out the test, we may come up with a significant percent of sound but dormant seeds, i.e., many seeds will not germinate even when supplied with optimum conditions: they remain dormant. Dormancy in seeds is a common phenomenon and is often a useful attribute for survival of species. Different types of dormancy exist in tree seeds that arise from either genetic characteristic or induced. Three major types are identified.

1) Exogenous (seed coat) e.g Acacia, Prosopis, Albizia and many other low land species, Podocarpus falcatus,
2) Endogenous (Embryonic)
3) Combined /double (seed coat and Embryonic)

In spite of its importance as survival strategy of a species, it poses problems to the nursery man. Such as irregularity of germination, occupation of nursery beds for the seedlings for a long
period of time, increased production costs. Therefore, anyone body who do in these areas must know about his/her seeds behavior.

E. Seed pre-treatment
There are different methods of seed pre-treatment depending on the type of dormancy. Very often, a method for a certain type can also do for another type so as to hit ‘two birds with one stone’

a) Physical Methods
For seeds with exogenous dormancy (impermeable, hard seed coat), common techniques of pre-treatment finclude Scarification which involves rubbing the seed against a rough surface (file, sand paper, concrete mixers, seed scarifiers or any other abrasive material), or nipping/ nicking so as to make a very small ‘hole’ sufficient to allow water. This method is more applicable to seeds with seeds coat dormancy, but not for resinous or pulpy fruits. However, nutcrackers can be used for such fruits with hard coats/ nuts.

i. Hot/Cold water treatment
Such treatments combine the effects of softening hard seed coats and leaching out chemical inhibitors. Some seeds that have little resistance to germination may respond well to soaking for 24 hours in water at ambient temperature. A more effective treatment, especially in hot climates, is alternate wetting and drying of seeds.(E.g.oneday's soaking;3-4day’s drying). In hot water treatment seeds are usually placed in to boiling water which is immediately removed from the heat source and left to cool gradually, the seeds remaining in the water for about 12hrs. The ratio of water to seeds can be determined by experiment, and may vary considerably according to species; 2-3 time, 4-5 time, 5-10 times. Byand large, the volume of watershould bemuch higher. Refer part VII number 15.3.3(c),UGIS of 2015

NB: Care should be taken not to damage the embryo by excessive heat; especially if the seed coat is permeable.

b) Chemical treatment/Acid treatment
Concentrated H₂SO₄ (95%) is commonly used to treat dormancy especially for seeds that have been kept in store for a long time.
Materials: Acid (SG= 1.84, 95% pure), acid resistant containers, screens for handling draining & washing seeds, abundant supply of water for rinsing.

Procedures: Allow seeds to come to air temperature; thoroughly mix seeds; immerse seeds in the acid (Duration based on experiment); Remove seeds from acid, rinse seeds with abundant water (5 to 10 min); spread the seed in a mat for drying. Care is required in handling acid (safety); excessive application of acid may damage the seed. It requires skill.

c) Cold stratification
This usually applied to treat physiological dormancy; mainly for temperate species, but also effective for some tropical highland species stratification (strictly) refers to the method of placing seeds in layers alternating with layers of a moisture retaining medium such as sand/peat and keeping them at a cool temperature for a certain period, which is commonly between 20-60 days but varies considerably from species to species. Soaking in cold water/moisture medium at temperature of 3-5 °C.

F. General points about seed testing
Seed testing is the cornerstone of all other seed technologies. It is the means by which we measure viability and all physical factors that regulate the use and maintenance of seeds. Everything done with seeds should have some test information to guide work and ensure high quality. Seed tests tell us: If seeds are worth collecting, If handling procedures are correct, and How many potential seedlings are available for regeneration and it performance.
2.1.2. Nursery establishment and maintenance

Tree nursery is a place where young plants can grow with special care and protection up to the point where the young material is able to establish and flourish under field condition. Simply it is a place where young trees or other plants are raised for transplanting, for sale, or for experimental study. Urban nursery provides countless varieties of shrubs, grasses, vines, fruits and ornamental trees to consumers and landscapers alike.

We need to establish nursery because of: inapplicability of direct sowing of seeds for all of tree Species. Newly germinated for most tree species fail in competition with other plants and it is impractical to get each tiny seedlings, 3 to 4 m apart, the care needed for survival; the need of seedlings in large number; enables foresters to produce healthy and vigorous seedlings.

A. Types of Nurseries

Nursery can be classified based on time duration the nursery is supposed to serve, scale of production (related to size of the area to be afforested) and/or number of seedling produced per year and availability of suitable nursery site. Additionally, it can be classified based on owner
ship. Nursery can be categorized into: permanent nursery, temporary nursery and extension nursery.

a) Permanent Nurseries
Permanent nurseries are large centrally located nurseries that are established where there is a demand for large number of seedlings for long period of time (>5 years). Produce several hundreds, thousands or millions of seedlings each year. Particularly, annual seedling production is more than 0.5 million. Usually they have permanent workers (trained foreman or forester) hence, have a better control in most activities and produces quality seedlings. Additionally those nurseries use sophisticated methods of raising seedlings and have better control over soil mixture, shading and watering than temporary nurseries. Their establishment cost is high. Many of the governments and community nurseries are permanent nurseries.

b) Temporary nurseries
Temporary nurseries are also called flying/satellite/Field/ nurseries. Because they can be decentralized in nature (can be abandoned or shifted to other places). These types of nurseries are established for a short period of time (usually < 5 years); provide a limited numbers of seedlings for local need. They can be located adjacent/near/within the planting area hence, reduce transportation cost and time between lifting and planting. Additionally, there is less planting shock (minimizes damage of seedlings) leading to seedlings better survival under field condition. Reduce disease transmission, seedlings transportation can be done by workers themselves. Use the simplest methods of raising seedlings, requires less capital investment (cheap) and more easily manageable. Can be done by temporary workers (often less supervised) which usually results poor quality seedlings. E.g. Many of Ethiopian farmers’ nurseries Used in Social or Community forestry programs. These types of nurseries established to provide seedlings of many species useful for the local community, for amenity, fodder, fuel wood, post and poles, fruits etc. Depending on ownership, Nurseries can also be categorized as Private (owned by private or individuals), Community (owned by community) as well as GO’s (owned by government). In Ethiopia, many large nurseries are government nurseries.

B. Basis for nursery establishment
Successful nursery establishment and management operations depend on many factors. It includes; selection and development of suitable site, efficient supervision and management,
adequate planning, orderly timing of operations, use of appropriate cultural measures and protection from pests, diseases and other damages.

a) Site selection for an urban nursery

Choose the best possible site based on preliminary survey of areas. The use of available maps may facilitate identification of sites. Selection of site for nursery should be done with considerable care and thought. Make careful analysis before establishing nursery. Site selection inevitably requires a compromise between different factors. Before a field is used, collect the history of the field, including previous crops grown and types of herbicides and pesticides previously applied. Choose a site with well drained soils, free from flooding, high water table, and rocks.

Some basic Questions to ask before deciding to establish a new Nursery:

1) What are the characteristics of the planting site and GI (remote, easy access)?
2) What are the market prospects? If the intention is sale
3) Will the nursery compete with the already existing ones?
4) Can already existing nurseries meet the needed planting stock?
5) Are labors and trained personnel available?
6) What equipment is available on local markets?
7) What is the legal framework for establishing a new nursery?
8) When selecting sites, you have to consider two important factors; these are factors important for seedling growth and factors important for nursery management. The following these factors are further classified in to four factors:

b) Ecological factors:

Consideration of this factor is important for best growth of seedlings.

Ecological factor important mainly include: climate (rainfall, temperature and wind);

1) Topography: (avoid areas with large stones and rocks, choose almost level areas, 2 -3% slope, avoid exposed windy hill topes as these would be too dry & in higher altitude too cold, avoid valley bottoms as these are subjected to water logging & frost pockets, avoid areas where flooding occurs at any time of the year)

2) Soil: - is most important factors for choosing nursery site for producing bare-rooted seedlings using native soils; the site should have appropriate soil texture, depth, soil pH, and soil; For potted seedlings choose nearby areas where there is adequate sources of
soil mixture (help to reduce transport distance & cost); clay soils with high shrink- well capacity must be avoided (in all cases)

3) Choose areas with soil which are fine sand or sandy loam for bare-root seedlings (as such soils are not compacted, has good drainage, fewer root rot problems, causes less damages to the roots during lifting. Select sites with soil pH value between 5 - 7 for broad-leaved, and 4.5 - 6 for conifer species. A valuable guide in selecting a potential productive site is to look at the past agronomic history of the site and native vegetation of the site.

4) Water: Is one of the best criteria for choosing nursery sites; Select site where there is permanent water supply (both in quantity and quality) for current and possible future requirements; Sources could be Springs, Small streams, rivers, ponds, wells); For rough estimation 50 liters/1000 plants/day are needed or 10 - 20 liters of water/ day/ productive area.

c) Economic factors: is important for management of nursery

1) Land availability: Select a site large enough to allow the production of intended number of seedlings. If possible, avoid selecting land, claimed by many individuals

2) Labor and Material supply: The sites for selection should have sufficient number of workers willing to work during pick periods of seedling production. Some required materials to condition soil texture; water holding capacity, drainage, and fertility should also be available.

3) Accessibility and facilities: consider the availability of transport facilities, good communication (Roads, telephone lines), electric supply, housing for staff and laborers.

d) Social factors

Consider growth of population, wealth, mode of life of the people as they influence the acceptance of establishing nursery and their products.

e) Biological factors

Select site free of serious insects, diseases, weed, pests, as these can affect the growing seedlings in the nursery.

C. Layout and design of a nursery
a) **Nursery Site Preparation**: Steps to be followed in site preparation for establishing a new nursery:

1) Felling all the trees on the site (up to 10 m away from proposed boundary.
2) Remove any stumps, termite mounds and big stones
3) Plough the area thoroughly and remove all roots.
4) Peg-out the location of blocks and roads.
5) Level each blocks using leveling (Distribute top soil evenly, avoid sub soil).
6) Board with rakes.

D. **Components of Nursery area**:

Components of nursery are elements that a nursery especially Permanent should include. A given tree nursery has two major components (areas); the productive and non-productive areas. The nursery productive area includes seed bed, transplanting and reserve beds. While the other major component of a tree nursery which described as non-productive area includes administration area, buildings area includes tools and equipment store, seed processing store, seed drying, seed store, guesthouse, shading, and shelter for plants, access roads and inspection paths, windbreaks, fences and hedge, compost site, and irrigation system.
E. Size and Shape of a Nursery

a) Shape of Nursery:-

The shape should be as compact as possible. Approximately Square shape is recommended, to minimize the length of the boundary for fencing and hence save cost and time, and keep the distance between any two places /points/ in the nursery at a minimum. If not a square shape, rectangular shape is convenient. For smaller nurseries, a rectangular shape with blocks spited along the longer side of the nursery beds may be more economical.

b) Nursery size:-

There is a lower and upper limit in nursery size. The lower is defined by the higher production cost/plant and is ca. 250,000 seedlings/year. The area that should be supplied by one nursery limits the upper size. The upper limit is ca. 5 million seedlings/year.

1) Factors that govern the size of nurseries:-
Level of annual plant production (related to area to be planted annually). E.g. a common nursery size has an annual plant production of 0.5-2 million seedlings. Method of raising seedlings: containerized seedlings occupy more bed space than bare-rooted seedlings. Hence increases the size of nursery. Areas required for different buildings, roads, paths, and irrigation system. Nursery life of plants: Seedlings demanding long period of time to attain the suitable size need more space and hence nursery size becomes larger.

c) Nursery Area calculation:-
To calculate the most appropriate nursery size, you need to know the:

1) Required productive area (Pot beds, seedbed, and reserve beds)
2) Non-productive Areas (areas needed for roads, paths, buildings, fences, windbreak etc) 
   & is mostly twice that of Productive area.
3) Area for possible future extension (may account 20 - 25% of the total nursery area)

Example- A forestry project planned to raise 500,000 seedlings annually including replacement of last year’s failures. A polyethylene tube having 10 cm lay flat will be employed to raise the seedlings. Expected nursery failure is 10%. Then calculate the total nursery area.

Procedures for calculating the total area -
First Step Calculate the productive area

Annual seedling production = 500,000
Expected Nursery failure (10 %) 500,000*0.1 = 50,000
(Replanting included)  
----------
Total seedling production = 550,000 seedlings/year

Calculate area needed for transplant/pot beds:-
Depends on the size of polythene tube. Polythene size 10 cm lay flat.
To calculate the diameter of the pot, use the following formula: -
\[ C= \pi D \]
\[ D= \frac{C}{\pi} \]
Where, \( D \) = diameter of polythene tube
\( C \) = circumference of the polythene tube
\( \pi \approx 3.14 \)

C of 10 cm lay flat polythene tube is double of 10. Accordingly the corresponding D will be 20/3.14 = 6.4 cm
To calculate the number of tubes/m² use the formula \[ N= \left( \frac{100}{D} \right)^2 \]
Where, \( N \) = is tightly packed filled tubes and \( D \) = diameter of the pot in centimeter. Or 
\[
1 \text{pot} = 0.064 \text{m}^2 \times 100 \text{cm} = 6.4 \text{cm}^2
\]
15 pots can be stacked in a straight line on one meter. Therefore the total number of seedlings/m² is \( 15 \times 15 = 225 \) potted seedlings/m².

To calculate the total area for pot/transplant beds:
\[
1 \text{m}^2 = 225 \text{pots}
\]
\[X? \quad 550000 \text{pots}
\]
\[
550000 \text{pots} / 225 = 2444 \text{m}^2
\]
Note: To calculate the transplant beds for bare rooted seedlings, take spacing between rows and plants. Ex. if the distance between rows is 20 cm and between plants 5cm, the density would be 100 seedlings/m².

Calculate seedbed area, which are usually 20% of the transplant beds:
\[
2444 \times 0.2 = 489 \text{m}^2
\]

Reserved beds area, which is 20% of, transplant beds and seed bed:
\[
2444 + 489 = 2933 \text{m}^2
\]
\[
2933 \times 0.2 = 587 \text{m}^2
\]
Total productive area becomes:
\[
2444 + 489 + 587 = 3520 \text{m}^2
\]

Second step is to calculate the non-productive area: As it can be seen practically more non-productive area (Area for access roads, paths between beds, tools store, seed store, seed processing room, soil dump, compost, fences and wind breaks, buildings and others are needed and should be calculated.

As a rule of thumb, the non-productive area will be twice the production area i.e. seed/pot beds area. Therefore, the non-productive area of the above example will be 2933 * 2 = 5866 m².

Total Nursery area = Productive + Non-productive
\[
3520 \text{m}^2 + 5866 \text{m}^2 = 9386 \text{m}^2
\]

If 20% reserve for future expansion is needed the total nursery area becomes:
\[
(9386 \times 0.2) + 9386 = 11263 \text{m}^2 \text{ i.e. 1.13 ha.}
\]

F. Nursery Fence, Hedge, wind break
Nursery fence or hedge is needed to demarcate the boundaries, protect them against animals and to some extent winds.

a) **Common Fence types :-**
Fencing may be done in three ways: barbed or plain galvanized wire (or partly of each); wire mesh (chicken net fence); electric fencing. All fencing types require fencing posts that should be sound, straight, suited size to the purpose, and properly treated against insect attack. Refer part VII, number15.3.2(f) and 15.4(a), UGIS of 2015

1) **Hedges**:
A hedge is a one or two rows of seedlings that are planted in a straight line. It can serve as shelterbelt in protecting seedlings against strong winds. The hedge can be considered as live fences. Hedge has both advantage and disadvantage. The disadvantages are it may take 2-3 years to grow it to full size, needs continuous and regular tending (hoeing, weeding watering), needs clipping at least twice a year. Despite to its disadvantage, it has a lot of advantages like cheap to establish, has long life, gives more protection against animals and winds and also pleasant to look (Figure 6). Species to be used in hedge should be; grows fast, able to grow in a very restricted space, withstand repeated clipping, ever green looking, long lived. E.g. *Cupressus lusitanica*, *casuarina*, *Dodonea Viscosa*, etc. A fully-grown *cupressus* hedge can grow up to 2m height and 1m wide at base (can be attained at 3-4 years age)
Construction of hedge

Procedure to establish a hedge:

i. Allocate a 2.5 -3m wide strip for the hedge along the boundary of the nursery

ii. Dig a 1m wide strip in the center of the strip to 30cm depth.

iii. Mark out 2 rows, 50 cm apart, and 25 cm from either side of the cultivated strip.

iv. Plant vigorous seedlings (30cm tall) at 50 cm interval along each line so that the seedlings in one row are staggered against the other row of seedlings.

v. Manage them properly (watering, weeding).

vi. Start clipping lightly, to form a shape of hedge, wider at base and tapering upwards, when plants are 1.5m tall.

2) Wind breaks:-

Wind breaks are three or four rows of suitable trees and shrubs that are planted on windward sides of production areas and germination beds or around the nursery. Help to reduce drying,
eroding, and abusive effects of winds on growing seedlings, sometimes they protect from animals. During species selection for Wind breaks avoid selecting those species whose root systems compete with bare root seedlings for water and nutrients. Any insect or disease outbreak in wind breaks should be controlled quickly to reduce the risk of spreading to nearby nursery seedlings. Refer part VII number 15.4(b), UGIS, 2015

G. Compartment Division and Bed construction

a) Compartment:-
Compartment is the basic production unit with beds running parallel to the shortest side. One compartment can hold 10-20 beds. It is good if a single compartment can contain 10 beds to shorten the walking distance during watering. Germination compartment, buildings, as well as soil storage occupy one compartment each. For management purposes several compartments can be combined to form blocks that can be framed by hedges.

b) Bed construction:-
Seedbeds are mostly 1 meter wide (enables someone to reach the center of the bed during weeding, watering). The length of bed could vary from 5-20m. Preferably all beds should have equal length. Usually 1 m paths are left in between the beds.

1) Procedures for seed bed construction:-
   i. Level the site where bed is to be constructed and firm the soil.
   ii. Mark out the required size and shape of bed with peg and cord.
iii. Erect reverting boards 15 cm*3-4 cm in size around the marked area.

iv. Place a layer of gravel having 3 cm thickness or sand sieving to a depth of 5 cm in the bed followed by smoothing and pressing lightly with a flat board. Apply 2-3 cm thick layer of un-sieved forest soil on the top of gravel for good drainage and to act as filter layer for fine seedbed soil that would be leached down.

v. Fill the remaining part of the seedbed to the top with seedbed mixture.

vi. Level the soil with flat board.

vii. Firm the soil in bed using hands to avoid air space/unfilled space. Later firm the soil using flat board.

viii. Protect the surface of beds with a thick layer of green grass and leaves.

Seedbeds should be constructed orienting in East-West direction to have a balanced shade effect. The road system should minimize the need for transport of materials and seedlings with vehicles. If seedling delivery relies on transport with vehicles, use access ways wide enough to allow for turning (esp. if trailers are to be used). Make the road surface sufficiently stable to support the vehicles during the rainy seasons. In order to provide full access from all sides to buildings, soil dump and germination compartments, construct additional feeder roads.

2.1.3. **Irrigation system:**

The layout of the irrigation system should follow the natural slope of the nursery site (enables easy distribution of water in all directions). Use gravity to distribute water (Whenever possible). The discharge of all the water Sources i.e. surface water which includes spring, river, streams, lake and Ground water which includes wells + pumping system) should considerably exceed a daily requirement of about 8mm as it avoids construction of expensive storage tanks and /or ponds.

An irrigation system is best designed during the planning for field layout and planting strategy. The main irrigation trunk lines will need to be buried in the field, usually along roads, with the valves located at convenient intervals. Plan for a method of draining irrigation lines to avoid damage caused by winter freezing. If a traveling gun will be used for irrigation, consider this in the plan as well.

Hose, reel or gun types of irrigation are designed to apply large volumes of water. For optimal growth, nursery stock may require 1 to 2 inches of water per week. Generally, 1 acre inch is equal to approximately 27,000 gallons of water. Overhead irrigation provides water to large areas.
causing weed seeds to germinate which increases weed competition. Other disadvantages of using overhead irrigation are water waste due to evaporation, the potential for erosion and runoff, and increased foliar diseases. Drip irrigation is a better choice for irrigating field grown nursery stock.

A. Drip Irrigation:
Drip irrigation is very efficient and since it remains in place, can be used as frequently as needed to keep seedlings growing. Since water is placed only in a band down the seedling row, less weed competition occurs, especially during dry years. In drip irrigation, water is applied directly to the soil surface gradually over extended periods of time (for example 1.0, 2.0, or 5.0 gallons per hour), which results in less water lost to evaporation or runoff.

Because drip irrigation applies water only to the root zone of the nursery seedling, roots tend to concentrate within the wet area. Less fertilizer is needed when applied through drip irrigation because of improved efficiency in fertilizer delivery and use. In addition to a reduction in fertilizer use (and costs), other advantages of drip irrigation include reduced water consumption and reduced potential of environmental impacts of erosion and nutrient runoff.

Drip irrigation requires regular maintenance since emitters are prone to damage by animals. A drip irrigation system also requires very clean water, free of sediment and minerals. Well water generally needs only minimal filtration for drip irrigation use, but surface water from rivers or ponds usually calls for sand media filters so that it does not plug drip emitters.

a) Drip Irrigation Considerations

1) Water source:-
Organic materials like plant materials, algae, and small living organisms as well as inorganic sand, silt, and clay are likely to be of concern in surface water like a pond or stream. Well water is likely to have some sand, silt, or clay particles, although not as much as most surface supplies. These particles can block the small diameter emitters in a drip system. Surface water might have contaminants from runoff, including diseases like Phytophthora which can enter fields through irrigation water. Filters are used to remove particulate matter.
2) Soil:—

The soil type determines the soil wetting patterns. Soil wetting patterns in turn influence depth of the drip tape and the distance between emitters. The duration and frequency of irrigation are also determined by the soil type. Over-watering can move fertilizer away from the root zone. In sandy soils, water goes primarily downward rather than horizontally so emitters should be at relatively close spacing. Spacing between emitters can be greater in heavier soils as there is considerable lateral movement of water. In sandy soils, irrigate more frequently but for shorter periods of time. In heavier soils, irrigate less often but for longer periods of time. In both cases, this should lessen the chance of leaching fertilizers away from the root zone. Installation and operation of a trickle system requires expertise. Consult with a knowledgeable professional. A poorly designed system can result in over-or under-watering and clogged lines. Any or all of these problems can completely offset the potential cost savings from using drip.

2.1.4. Compost preparation

Compost is a natural product which consists of a partially decomposed mixture of organic residue (crop residue, weeds, vegetation wastes, either with or without the addition of some animal waste and which used for fertilization and conditioning of soil. Compost can increase soil fertility through improving structure and structure stability of the soil, improves infiltration and water holding capacity of the soil, and thus avoids losses of soil due to reduced runoff. The main source of organic matter is the plant and animal residues. Proper planning of compost making in a nurseries will enable:

- Recycling of all waste materials produced in the nursery. E.g. grass, legumes, fertilizers, branches weeds, instead of being burnt or disregarded. Production and availability of compost throughout the year.

Compost is done by the action of microorganisms in a warm, moist and aerated environment. The aim is to maximize the use of locally available organic waste material. Compost increases:

- Soil organic matter content which improves water retention, better workability and improve structure and structure stability leading towards resistance to erosion. Compost also contributes as Sources of nutrients.
A. Compost preparation methods

Basically, compost can be prepared in two ways. These are the “Heap” and “pit” methods

a) Heap method
1) Done in an open condition
2) Requires less labor (no digging)
3) Managed easily b/c the compost is above ground surface
4) No problem of excess water b/c it is freely drained
5) Is easy to turn and be mixed for aeration

b) Pit method
1) Done in a pit
2) Requires much labor (involve digging)
3) Difficult to control temp., moisture and aeration b/c it is under pit.
4) Problem of water logging rainy season which reduces the breakdown of organic residue
5) Is difficult to turn and mix for aeration

i. The pit method is recommended in the following circumstance
   - In dry areas with water shortage
   - During the dry season if the nursery has problem of water surplus
   - In nurseries located over 2600m where the temperature is low especially during the night in a pit temperature will be higher and more constant than in a heap

Figure 6: Process in pit compost preparation
B. Site selection for compost preparation

Site located under a natural shelter (trees, live fence, and wind break) in warm (below 200m area) where there are no natural shelter, we prepare light and simple roof to reduce moisture loss through sun and wind which enhance the process.

As much as possible the site should be located:

- Near the water supply to minimize labor requirement
- Somewhat far from the everyday work to avoid smell of decomposition flies etc.

**Remember:** Polythene, rubber, plastics, pottery, and pieces of materials or wire (any inorganic materials) must be avoided since they can’t be broken down. Additional compost materials include:
- Animal manure: provide micro-organism to speed up the process (enrich the compost with N, P, and K (NPK)).
- Ashes: enrich the compost with P and K and increase micro-organism.
- Soil: provide micro-organism living to speed up the process sometime, chemical fertilizer (if available) e.g. Nitrogen fertilizer which speed up the breakdown of cereal straws.

a) Procedures

1) Select appropriate site
2) Collect organic waste, plant, animal manure, ash and other
3) Demarcate the proper area using wooden sticks: shouldn’t wide 2m and 1.5m high. Should be long as necessary.

4) 1st layer: spread organic residues (20m tick) on the surface firmly and be given good watering.

5) Spread ash over the compacted layer or plant waste (quantity ½ kilos/square meter/layer).

6) Spread farm yard manure (a good amount of manure would be three kilos/square meter/layer).

7) Some soil should be spread (few spread for each layer)

8) Repeat the procedure 1-7 until the heap reaches 1.5m high. To improve aeration put bamboo in the centre every 2m spacing along its length.

9) Cover the heap with dry grasses or other dry plant residues in cold areas/above 2600m. The sides of the heap can be covered with the soil to keep the heap warm and avoid drying by wind.

10) Leave the heap for 3-5 weeks, by checking the moisture once a week.

11) After 3 weeks in kola 4 weeks in weyna-dega, 5 weeks in dega, the compost should be turned and mixed to aerate the heap.

12) Repeat the operation mentioned in number(10) for 1-3 times at the same interval and left the compost mature. 2-3 months in kola, 3-4 times in weyna-dega, 3-5 months in dega are enough to get ride of compost depending on the type of plant material. Refer part VII, number 15.3.5 (a-k), UGIS, 2015.

2.1.5. Raising seedlings

A. Vegetative propagation

a) Introduction

One of the biggest problems associated with forestry and agroforestry technologies is multiplication on a large scale of trees and shrubs. The common way by which plants regenerate naturally is propagation by seed. For research and rapid improvement of undomesticated species, however, vegetative propagation methods offer several advantages. The concept of vegetative propagation is that an exact copy of the genome of a mother plant is made and continued in new individuals.
The practice of vegetative propagation of fruit trees dates back to ancient times. The most important and widely applied vegetative propagation techniques for tree species are the propagation by stem or root cuttings, grafting and budding, and various methods and techniques of layering and micropropagation. The justifications for using vegetative propagation include maintaining superior genotypes; problematic seed germination and storage; shortening time to flower and fruit; combining desirable characteristics of more than one genotype into a single plant; controlling phases of development and uniformity of plantations. Vegetative propagation might be a suitable and cheaper alternative to seedling particularly for recalcitrant seeds of the tropics where germination and storage is a problem.

b) Clone selection and collection
Targeted vegetative collection of tree germplasm creates the potential that superior trees are made available more quickly to farmers with earlier expression of desired products and uniformity of growth form. However, such collection may also lead to a narrowing of the genetic base of cultivated material and can be both costly and time consuming. The relative merits of vegetative sampling of clones in the field will depend on the biology of the species and the situation in question - these must be evaluated on a case-by-case basis for any collection.

c) Collection principles
Germplasm may be collected for a number of reasons. These include: for immediate distribution to farmers or other users; for conservation purposes and for the selection of superior germplasm in tree domestication programs. Normally, germplasm is collected in the form of seed, although vegetative sampling is another option. A number of advantages are associated with vegetative sampling of germplasm compared to seed collection. These include the following:

Collection of an exact genetic copy of the sampled tree is taken during vegetative collection. Hence, if selection for superior trees is possible during collection, the favorable genes and adaptive gene complexes of those individuals are maintained. Targeted vegetative collection can then lead to increased efficiency in the selection of superior quality material when compared to seed collection. This is because most trees are out-breeding species, which means that only 50% of the nuclear genome of seed is contributed by the mother tree. Collection of seed could result in the loss of favorable genes and adaptive gene complexes from the mother trees.
Accelerated expression of important characteristics may be exhibited by vegetatively sampled material, depending on the method of collection and the age of the tree. For example, marcotted material of fruit trees normally produces earlier than if sampled as seed. This has advantages both for the evaluation of germplasm in tree improvement programmes and in the direct distribution of material to users. In the latter case, farmers probably receive benefits more quickly from collected material;

Collection is possible when no seed is available. For some species, the appropriate time for seed collection is difficult to predict and varies greatly between years. Some species do not fruit in some years, or, if out breeders, are unable to produce fruit at all, due to genetic isolation, as a result of population fragmentation. In these instances, the ability to collect vegetative material provides the only method of obtaining germplasm.

1) Potential limitations
Phenotypic selection during collection could be ineffective. Normally, characters can only be selected for in the field, if they are of high heritability, because of the influence of a non-uniform environment on character expression. While some characters of interest may be of high heritability (possibly, fruit size and sweetness), other traits may not be (e.g. tree form). Little work has been carried out in determining the efficacy of phenotypic selection in the field.

Vegetative collection at times suffers from practical difficulties. The techniques involved in collection may be difficult (possibly requiring considerable prior research for optimization) and time consuming. Vegetative material is perishable – it must therefore be handled carefully in the field (Leon and Withers 1986) and cannot normally be stored for long periods of time. Sometimes material is bulky and difficult to process. Quarantine regulations may be stricter due to the increased potential for the transmission of viruses or other diseases, when compared to seed.

Due to practical difficulties, vegetative collection tends to focus on a small number of trees from any given provenance. This is most likely to lead to a narrowing of the genetic base in collected material compared to the population from which it is collected. This is particularly true for trees, which normally show considerable variation within populations.
Whether or not vegetative collection is appropriate in a given situation will depend on the biology, use and desired level of improvement of the species in question - these factors must be assessed on a basis before collection begins. A targeted vegetative approach is most appropriate for those tree species that; produce high value products (e.g. some fruits); are outbreeders; have a long maturation period before fruiting; produce recalcitrant seed and whose important characteristics are under strong genetic control

Low value species used for service functions (e.g. for soil fertility improvement or fodder), with short generation times and prolific production of orthodox seed, are often better collected as seed. During collection for evaluation in genetic improvement programmes, it is important to sample material from a range of provenances across the geographical range of a species, as well as across ecological gradients (such as altitude or rainfall clines) that occur within the distribution of the taxon.

2) Collection guidelines

The selection and collection of germplasm is best carried out in a participative manner with potential end users. First, this involves a determination of those species which users are interested in growing. Second, suitable collection methods for those species must be defined through learning experiences or experimentation from users. Third, those characteristics of a species, which are important to users for which improvement would be desirable, must be determined. Collections should then be carried out directly with local communities. Targeted sampling should be based on the important characteristics that end users have defined.

d) Vegetative propagation techniques

1) Cuttings

Taking stem cuttings is perhaps the most common way to vegetative propagate shrubs or trees. The process is relatively simple requiring only a limited area for reproduction, whilst a single mother- or stock plant can yield many cuttings. A large number of ornamental plants are propagated this way, but little is known about the use of this method for most agroforestry trees. The following paragraphs briefly describe some of the underlying principles of the cutting and rooting process, highlight the different factors influencing this and look at the different steps leading to the successful propagation of trees and shrubs through this technique.
i. **Types of stem cuttings:**

There are two main types of stem cuttings: Softwood cuttings (leafed cuttings) are young soft succulent cuttings with leaves (sometimes pruned). Hardwood cuttings are made of matured, dormant hardwood after the leaves have been shed. Tip cuttings possess terminal buds; basal cuttings are without terminal buds.

Some general characteristics of the two types are mentioned below:

<table>
<thead>
<tr>
<th>Softwood cuttings</th>
<th>Hardwood cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves on the lower part removed, those on the upper part retained and often pruned.</td>
<td>All leaves are shed.</td>
</tr>
<tr>
<td>Young branchlets. Always tip cuttings.</td>
<td>Young branches. Central and basal parts of the shoots (basal cuttings), or end of the shoots (tip cuttings).</td>
</tr>
<tr>
<td>Best cuttings have some degree of flexibility but, is mature enough to break when bent sharply.</td>
<td></td>
</tr>
<tr>
<td>75–125 mm long with two or more nodes.</td>
<td>10–75 cm long with at least two nodes. 6–25 mm diameter.</td>
</tr>
<tr>
<td>Basal cut made just below a node.</td>
<td>Basal cut made just below a node. In basal cuttings the top cut is made 15–25 mm above the node.</td>
</tr>
</tbody>
</table>

The cuttings can sometimes be reduced to consist of only a small piece of stem with a single leaf and an axillary bud attached, i.e. a single node. Such cuttings are called nodal cuttings. They are especially useful when the cutting material is scarce.
Branch indicating places to select hardwood cuttings.

Note: There is a strong polarity in cuttings. When rooting hardwood cuttings, care should be taken not to plant the cuttings upside down. When it is difficult to distinguish between the top (distal end) and the base (proximal end), it is advisable to make one of the cuts a slant.

ii. Rooting process

The following diagram illustrates the different stages in the rooting process of cuttings and indicates which exogenous and/or endogenous factors influence these stages.

Different stages in the rooting process, and the factors influencing them

The rooting of stem cuttings is a complex process resulting from a combination of many factors. The success of taking cuttings starts with the status of the stock- or mother plants and this is affected by several endogenous and exogenous factors. Once the cuttings are harvested from the mother plant, several measures need to be taken to ensure proper conditions for the rooting process. This starts with a healing process, the formation of new cells, the induction of root formation, the linking up or bridging of these roots with the existing vascular tissue of the cutting stem, elongation of these newly formed roots and finally the development of a new functional
plant from the cut stem pieces. Again, several exogenous and endogenous factors influence the success of this process.

- **Factors affecting the rooting process**
  
The most important factors, which influence the success of rooting cuttings, will be briefly described. They are: the rooting substrate, humidity, plant hormones, leaf area, light and temperature, and plant hygiene. Most crucial factor is the water stress since the cuttings may easily desiccate until they have formed water-absorbing roots. In general, the humidity must be kept high during root formation, e.g. by keeping the cuttings under a misting system or at least under a cover. Evaporation from softwood cuttings can be restricted by partial leaf pruning. Cuttings should be rooted under shade. The requirements and tolerances in terms of light and temperature etc. varies according to species. Cuttings are easiest rooted under tunnel or greenhouse conditions, since several factors can be manipulated and controlled under these conditions.

iii. **Preparing cuttings**

  Management of stock plants: Some important rules for the management of stock plants are: Establishing stock plants as close as possible to the propagation area; Pruning the stock plants regularly (twice a year) to encourage production of good shoots and maintain juvenility of the vegetative material. Always conserve one pair of feeding leaves on each plant; using fertilizer to accelerate growth on nutrient deficient soils; recommended plant spacing for most species; 1-2 m between rows, 0.5-1 m within each row; Separating different clones from each other and label them clearly. Allow some clones to grow as to express the clonal characteristics of the mature trees and growing stock plants under light shade, for example intercropped with *Calliandra* or *Leucaena*.

iv. **Taking cuttings**

  Cuttings should be taken early in the morning before the sun is hot, as this will keep transpiration and thus drying out to a minimum; Trim leaves before the shoots are detached from the stock plants as this reduces waterloss. Leaf areas for optimum rooting vary with species; however, 50 cm² seems to be the recommended leaf area prior to full investigation on this factor for different agroforestry species. The leaf area should allow for a balance between photosynthesis and transpiration when cuttings are under the non-mist propagator; Use a polyethylene bag that is
moistened inside to carry the shoots; Keep the collected shoots under shade, without throwing or squeezing the bags; If you are carrying the shoots over a longer distance, keep them in a cool box – but ensure that the shoots do not directly touch the cooling elements; In the nursery, have all equipment and tools ready and well arranged in advance in order to keep cuttings moist and transfer to propagators without delay. Delay can cause the cuttings to dry out and is often responsible for rooting failure of cuttings in arid and semi-arid zones.

v. Rooting medium

Type and medium used for rooting cuttings depends on the species and the materials available. Following common rooting media are used:

- Water:
  Can be used for easily rooting species. Its great disadvantage is the lack of aeration. Artificial aeration promotes rooting and impedes rottening.

- Sand:
  The sand used should be fine enough to retain some moisture around the cutting and coarse enough to allow free draining. The sand should be washed and sterilized before use. Note: Seashore sand has a high salt concentration which may be toxic to some plants.

- Soil:
  Well aerated sandy loam is preferable. Due to the possible presence of root-borne disease, soil may need to be sterilized or treated with pesticides.

- Peat moss:
  Used together with other materials in order to increase the water holding capacity. Coconut husk: Widely used in humid tropical environments where it has the same use as peat moss. Industrial manufactured material such as Vermiculite, Perlite and Pumice are used separately or in combination with some other rooting media. Their advantage is their lightness, cleanliness and high water holding capacity. Note: pH of the rooting medium may be critical. Care should be taken when using a rooting medium with non-neutral pH.
e) propagation facilities

1) Mist propagation

A critical factor in the successful rooting of cuttings is the maintenance of a humid environment to reduce water-loss through transpiration. Mist propagation is a technically advanced system to achieve this. It uses a high-pressure irrigation system that produces a fine mist through special mist jets placed above the cuttings. The frequency and duration of a mist application can be controlled using a timer, a moisture sensitive switch or a so-called ‘electronic leaf’. Since this system is expensive and requires reliable electricity and water supplies, it is not recommended for places where these utilities may not be available or can be unreliable.

Demonstration for mist propagation

2) Non-mist propagation

A suitable alternative for maintaining a moist environment is the non-mist propagator. This is a simple wooden frame enclosed by clear or white polyethylene sheeting. The propagator is filled with a moist rooting medium and contains a reserve of water. To minimize the effect of light (quality and quantity) on rooting ability, propagators should be placed under uniform shade. If possible, a 60% shade cloth should be used to protect the propagators.

As described above, the temperature of the propagation environment is also an important factor in rooting success. In non-mist propagators, it usually varies between 28-30°C. In hot and dry zones, frequent watering of the propagator itself can reduce excessively high temperatures. Humidity also varies within the propagator. Humidity levels are about 90-100% after watering, however the level drops rapidly to as low as 40% when the propagator is opened. To maintain
high humidity, the cuttings and the air space within the propagator should be sprayed once a day with a hand-sprayer. Temperature and humidity are the main factors that should be constantly monitored within the propagators.

Demonstration for non-mist propagation

1) Post propagation care

1) Potting
Potting-up is a delicate process in vegetative tree propagation, where one can easily lose all the rooted material. Removing the rooted cutting gently from the rooting substrate using a small flat piece of wood; shaking off loose rooting substrate and place the cutting into a container which is already partly filled with a suitable, light but nutrient-rich substrate. Covering the exposed roots with substrate, pressing substrate firmly around the cutting, and water. Newly potted cuttings need to remain in a humid and well-shaded environment until shoot growth commences. Watering at this level should be done with care, preferably with a sprayer or a watering hose with a fine nozzle.

2) Hardening
Hardening-off is to gradually accustom potted cuttings to grow under ordinary nursery or field conditions. This is done through a stepwise decrease in the humidity previously needed for the rooting of the cuttings. Under the harsh environment of the Sahel, potted cuttings of Prosopis africana were kept in closed propagators for three weeks, whereas Bauhinia rufescens needed only two weeks. Afterwards, the propagators were opened during the night (1 week), then night and day, except on very hot days. Species differ in their requirements: Prunus africana roots well
but the hardening is more difficult, while Pterocarpus erinaceus, Bauhinia rufescens and Tamarindus indica root well and are relatively easy to harden.

g) Grafting

1) Principles and techniques

Grafting, the technique of combining two or more different plants, has been practiced for many centuries. In the tropics, grafting is practiced on a relatively small number of commercially important trees such as mango, citrus, rubber, and avocado. However, it is also a viable option to domesticate several under-utilized agroforestry tree species. Grafting is a technique of vegetative propagation that is relatively labour intensive and requires skilled and experienced people for successful and satisfying results.

In grafting, a scion from the genotype is united with a stock (root stock) from another plant. The stock is usually a seedling, rarely a rooted cutting or a planted air-layered branch. For a good result of grafting the root stock as well as the scion has to be in good conditions, and the two parts should be compatible. The best time of grafting is 1–2 months before leaf flushing when the scions have dormant vegetative buds, i.e. the dry season just before the onset of the wet season; or in cool climates the cool season just before the onset of the warm season (spring). At that time the buds are just about to sprout and the level of the plant hormone auxin is high. Grafting can be done in the nursery in which case the stock is growing in a container. For some species grafting can take place under field conditions, provided the graft union is well protected after the grafting.
Figure 8. Tree parts after grafting

Most tools and other accessories used in vegetative propagation can be purchased at garden / horticultural dealers.

<table>
<thead>
<tr>
<th>(a) Grafting knife</th>
<th>Grafting and budding knives: Several types and qualities available. The knives should have an edge of hard steel that will keep sharp for a long time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Budding knife</td>
<td>The grafting knife (a) has a straight edge. The budding knife (b) has a curved edge and a blunt end for opening the bark and inserting the bud.</td>
</tr>
<tr>
<td>(c) Double bladed budding knife</td>
<td>A double bladed budding knife (c) is used for patch-budding.</td>
</tr>
</tbody>
</table>
Sharpening stone: There are stones for oil and stones for water. The stone should be hard and have a plain surface. The best type has a medium grit stone for rough work and a hard fine-grit stone for final sharpening.

Pruner or secateurs: Several types and qualities available: For light pruning, e.g. thin cuttings and scions and for removal of leaves, a light type with straight blades is preferred. A strong type with curved blades is preferred for heavier pruning.

Grafting wax: Various types are commercially available. Some are hot types, which are melted before use and which harden when cooled down. The waxes are applied with a small paint brush. Vaseline can be used as an alternative.

STAGES IN GRAFTING
2) Rootstocks
Rootstocks are usually grown from seeds. Good material should be used for root stock, i.e. plants with a well-developed root system and resistance to soil-borne diseases. The seedlings are kept in the nursery longer and are grown to a bigger than normal planting size, since they have to fit with the scions. For most species the plants will be about 50–70 cm high when grafting takes place. Therefore seedlings should be grown in relatively big pots, i.e. at least 10–15 cm diameter, depending on species. The root stock is fit for grafting when the stem is about 0.6–1.2 cm diameter at the upper third. The root stock should be tendered carefully before and after the grafting.

i. Scion
Conditions vary according to species. Following characteristics are guidelines: Scions should be taken from the upper part of the tree. Scions should be taken from vigorously growing branches.
Scion length should be about 15–25 cm. Scion diameter should be according to the size of the stock, i.e. 6–12 mm in diameter. Scions should be without flower buds. Scions should have well developed vegetative buds in a dormant stage. The scions should be kept moist and cool until the grafting takes place. Grafting should be done as soon as possible after collection.

*Bud development:*

<table>
<thead>
<tr>
<th>Too early</th>
<th>Acceptable size</th>
<th>Acceptable size</th>
<th>Too late</th>
</tr>
</thead>
</table>

*The cut and joint*

A proper cut requires a very sharp knife with a straight edge. The cut should be clean and smooth with no fibers on either side. The cut should be done in one movement. Except from top cleft grafting, the technique implies fit cuts of stock and scion respectively. A cutting angle of ≈ 20° for splice, whip or wedge graft is suitable. It is important that the cut angle is the same in stock and scion since a different angle of two cuts will result in a bend junction.

The size of the scion and the root stock is compared in order to find fit pairs. The place of cutting at the root stock can also be adjusted to fit the size of the scion. When putting the two parts together they should fit so that there is as little gaps and exposed wood and cambium on either side as possible. Some examples of cuts and joints in top cleft grafting are shown at next page.
The two joined parts should have maximum cambial contact. If the root stock has a bigger diameter than the scion, the joint should fit in one side only.

A scion should never have larger diameter than the root stock. An example of a joint in splice grafting where the scion is considerably smaller than the stock is shown below.
When the two parts are brought together, grafting tape or string is wrapped around the joint. The wrapping should be tight and completely cover the joint. It serves 3 purposes: (1) It keeps the two parts together in a fixed position until they have grown together, (2) It restricts evaporation from the cut; (3) It excludes water and air, and entry of fungi at the joint.

Sometimes grafting wax or Vaseline is used together with the wrapping material in order to help sealing the union. The wax can be a cold type or a hot type. The hot type solidifies upon cooling and must be reheated just before use. It is important that the hot type wax be at the right temperature when it is used. If the wax is boiling, it will injure the plant tissue; if the wax is too cool, it will not flow easily into all the crevices in the bark, thus leaving openings for the entrance of air, water and fungi spores.

The hot type grafting wax can be home-made from basic ingredients of beewax, resin and tallow or other fat. The important characteristics of a grafting wax are the following:

Melting point: The melting point should be so low that the melted wax will not damage the plant tissue but so high that it will not melt when exposed to extreme field temperatures.

Viscosity: The wax should have a consistence so that it will be thin flowing and applicable in a wide temperature range, e.g. 50–70°C.

ii. Reasons for grafting and budding: The following are the main reasons why you may want to consider grafting or budding agroforestry trees:

- To multiply a tree that cannot be multiplied through sexual or other asexual propagation methods:
- To obtain a tree that combines both the good characteristics of one tree and the rootstock of another one:
- To decrease the amount of time that a tree needs to attain maturity (flowering, fruiting and seeding):
- To rejuvenate older trees through the use of young, improved material from another tree:

To repair damage caused to certain parts of a tree and to detect viral diseases.

3. Grafting and budding techniques

i. Top-wedge grafting

This is the method most commonly used, as it is simple and usually successful with both seedlings and older trees. It is often used in top-working older trees as it can be used with scions considerably thinner than the rootstock. In top-working older trees, two small scions are usually
inserted at either side of the cleft. In these cases it is important that the scions are cut so that the outside of the wedge is slightly thicker than the inside to allow for the larger circumference.

Figure 5. Top or wedge graft

**ii. Splice and whip and tongue grafting**

A long, slanting cut is made in both scion and rootstock and these are tied together. This method is simple but needs some practice to allow for evenly slanting cuts and for matching scions and rootstocks. When tying-in, care is needed to prevent inadvertently slipping when joining the pieces. It is the technique of choice for material with a very pithy stem.

A more secure version of the splice graft is the whip and tongue graft in which a second short vertical cut is made 2/3 from the tip of the cuts in both scion and rootstock. The ‘tongues’ of both scion and rootstock are then slit into each other and the graft securely tied in. The advantage of this form of grafting is a larger portion of cambial cells to match and an initial good hold of the scion into the rootstock. The method requires soft material and is often used with young plants that have only limited lignifications.
Splice and whip and tongue grafting

**Splice graft**

Useful in grafting small plant material, with a pithy stem or wood that is not flexible enough to permit a tight fit when a tongue is made as in the whip graft. Not much used in forestry.

**Technique:**
Simple technique that consists of only one slant cut of stock and scion, respectively.
whip graft

Useful for top grafting of small plant material, about 6–12 mm in diameter.

Technique:

1. The first cut is the same as in splice graft.
2. A second cut is made starting ⅓ of the distance from the tip to the base of the first cut on both stock and scion. This cut should not just split the grain of the wood but should follow along under the first cut, tending to parallel it.
3. The two parts are pulled apart.
4. The cut of the two parts are slipped together so that the tongues interlock.

Top cleft and wedge graft

Top cleft is used for the same type of material as splice and whip graft; wedge graft is used for bigger materials.

Technique:

1. The stock is first cut straight and after that a perpendicular cut is made in the center of the stump. For bigger material, a wedge is cut in the top of the stump.
2. The scion is cut in the form of a wedge (for big material, similar to that of the stock).
3. The scion is inserted in the cut made in
the stock. In case the stock is of bigger diameter, the cambium should fit at one side only.

4. Wrapping and possible waxing.

## Side Graft

The method is used when the diameter of the stock is considerably bigger than the diameter of the scion or where top grafting is not applicable. Used for broad-leafed evergreen species.

**Technique:** Various methods; the principle is that the top of the stock is not cut until the two grafted parts have united. Two methods are shown below:

## Veneer Graft

**Technique:**

1. A slanting cut is made in the stock which penetrates as far as the xylem and the piece is removed.

2. The scion is prepared so that the cut fits that in the stock.

3. The two parts are joined so that the two cambiums fit (at least at one side).

4. Wrapping and possible waxing.

5. The top of the stock is cut off just above the scion after the two parts have united.
Side-Tongue graft

Techniques:
1. A piece of bark and wood ca. ¼ of the stem is cut along one side of the stock. A thin downward cut is made forming a thin tongue.
2. A long cut is made at the scion; a second cut is made under the first forming a thin tongue as in the root stock.
3. The scion is slipped into the cut in the stock, the tongues interlocking so that the cambium matches at least at one side.
4. Tying and possible waxing.
5. The top of the stock is cut off just above the scion after the two parts have united.

Approach grafting with water bottle

A variation of side grafting used when there are problems with desiccation of the scion. Bottle grafting has been used successfully in e.g. *Eucalyptus* spp.

Technique:
1. A cut is made on the side to about ⅓ of the diameter of the scion and the stock respectively (best where there is a...
natural bend).

2. The two parts are united so that there is maximum cambial contact.

3. Tying and possible waxing.

4. The end of the scion is put in a bottle with water, which is attached to the stock.

5. When united, the top of the stock and the end of the scion below the graft union is cut.

Note: The scions used must be longer than in other grafting methods in order to reach the water in the bottle.

The water should be changed regularly, in order to avoid alga formation, and the bottle refilled when necessary.

### iii. Approach grafting:

This is a form of grafting particularly suitable for difficult combinations. Both scion and rootstock remain intact plants until a secure graft union has been formed, thus allowing both to use their own vascular system for assimilation and water uptake.

### h) Budding

A modified form of grafting in which only a bud is inserted in the root stock. The method is widely used in horticulture, but can also be used for forest trees. Graft budding may have a preference in following instances:

If grafting material is scarce (only one is used in graft-budding).

In order to overcome topophysis.

In some instances graft incompatibility problems can be overcome by graft budding.

Two general preconditions for budding should be observed:
Except from chip-budding, the budding should take place when the plants are in active growth and the bark is easily separated from the wood.

The inserted bud should be a vegetative bud and not a flower bud.

Several methods of budding are used. Some of the most common methods are shown on the next page.

1) T-budding

<table>
<thead>
<tr>
<th>Description</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A T-formed cut is made in the root stock vertical about 2.5 cm, horizontal about ⅓ of circumference.</td>
<td><img src="https://via.placeholder.com/150" alt="T-budding Illustration" /></td>
</tr>
<tr>
<td>A slicing cut of the budstick is made from ca. 2.5 cm under the bud to 2 cm above. The shield is cut free with a horizontal cut ≈2 cm above the bud.</td>
<td><img src="https://via.placeholder.com/150" alt="Slicing Cut Illustration" /></td>
</tr>
<tr>
<td>The bark of the T-formed cut in the stock is opened. The shield is inserted by pushing it downwards under the two flaps of bark.</td>
<td><img src="https://via.placeholder.com/150" alt="Inserting Shield Illustration" /></td>
</tr>
</tbody>
</table>

T-budding is used for forest and fruit trees with a diameter of 6–25 mm and a relatively thin and flexible bark that can easily be lifted. An inverted T-cut in the root stock is sometimes used in order to avoid water entrance. The bud should then be prepared correspondingly with the straight cut at the proximal end.
2) Patch budding

| Two parallel horizontal cuts are made on the root stock, about \( \frac{1}{3} \) of the circumference using a double bladed knife. The two cuts are connected at each side by vertical cuts and the patch is removed. | The budstick is cut similar to the root stock, horizontal with a double bladed knife and vertical at each side. The bud is removed. | The bud patch is inserted into the patch hole in the root stock. The patch may need to be trimmed at one side in order to make a tight fit. |

Used for forest and fruit trees with a relatively thick bark. The budstick should not be larger than \( \approx 25 \text{mm} \) in diameter while the root stock may be up to 10 cm thick. The bark should be approximately the same thickness.

3) I-budding

| Two parallel cuts are made | The patch containing the | The two sides of the bark |

| Two parallel horizontal cuts are made on the root stock, about \( \frac{1}{2} \) of the circumference using a double bladed knife. | The patch containing the bud is removed. | The two sides of the bark are removed. | The bud patch is inserted into the patch hole in the root stock. The patch may need to be trimmed at one side in order to make a tight fit. |
on the root stock using a double bladed knife. The middle of the two cuts is connected, using a vertical cut.

bud is cut off by the help of the two bladed knives.

of the I-formed cut are lifted and the bud patch is inserted.

Modified patch budding used when the bark of the stock is considerably thicker than that of the budstick.

3) Chip budding

Root stock: First cut is made at an angle of 45° downwards, ⅛ of the diameter. Second cut is made ≈ 25 mm above the first, going downwards, to meet the first cut.

Budstick: Cut as for the root stock. First cut is made 6 mm below the bud. Second cut is made ≈ 13 mm above the bud going downwards to meet the first cut. The bud with attached wood is removed.

The bud is inserted in the root stock.

Chip budding is used for small material 12–25 cm in diameter. Its main use is that it can be applied outside the active growth season when the bark is not slipping.

Note: Buds possess polarity. It is important that the bud is inserted in the right position, i.e. not upside down.
Once the bud has been inserted in the root stock the union is wrapped and sometimes waxed. Care should be taken that the bud is not damaged and that the bud is left fully exposed, i.e. not covered with wrapping material or wax. When the two parts have united and the bud sprouted, the top or the stock can be cut.

i) Layering

1) Principles and techniques
The term layering is used for all types of propagation in which roots are formed while the stem is still attached to the mother plant. Only after the root formation, the layer is detached and planted as a new plant. Layering is often used in species that are particularly difficult to root from cuttings, as the layered branches allow a continuous supply of water, nutrients and plant hormones to the place of root development. Dehydration, a common problem in cuttings, is prevented, as well as nutrient leaching, which often occurs under mist propagation. As layering beds are often used for many years, utmost hygiene has to be practiced to prevent the spreading of pests and diseases, especially nematodes and viruses. As layering methods are often used with species that are otherwise difficult to root, it can take several months until roots have formed on the layered branch. The most common layering techniques for agroforestry trees include, air layering, simple layering and stooling. In tropical fruit propagation, air layering is the most important technique. Even though these methods have been developed in the temperate regions with a distinct dormant season due to cold temperature, they can easily be adapted to tropical conditions where the rains largely determine the growing seasons.

2) Air layering or marcotting
Air layering or marcotting can be done with almost any woody plant and is an excellent method to propagate small numbers of individual trees. It involves the girdling of a relatively young shoot, thus leading to an accumulation of rooting promoting plant hormones at the cut, without hindering water and nutrient supply to the tip. The shoots should be young and vigorous yet woody enough to withstand the treatment; best is the previous season’s growth. It seems that the individual development of the shoot is more important than the season in which the marcot is set. Moss, coconut (coir) fiber, sawdust, vermiculite or mixtures of soil with any of these substrates have proved to be suitable. A little soil from under established trees can be added to the substrate to help in the rooting process, especially for species that require microsymbionts. In order to improve the survival rate of the rooted marcot, leaves are trimmed or completely removed and
the shoot partially severed a few days before harvesting. At harvest, the marcot should be immediately placed into a container with water and then potted up, using an appropriate light, but nutritious potting medium, and placed under shade, preferably under humid conditions, such as in a polypropagator.

![Fig.10 Air layering or marcotting](image)

Species that are commonly propagated by air layering include mango, Ficus spp., Citrus auriculiformis and Persea americana. It is a method that is most appropriate for humid environments but if care is taken, it can also be successful in drier climates. As for other vegetative propagation methods, sufficient moisture is the key to success and the set layers need to be inspected regularly and moistened as necessary.

3) **Simple layering**

Simple layering is usually done with many-stemmed shrubs that produce long and soft shoots after coppicing. Plants are coppiced at the end of the dormant season and the developing young shoots are bent down and pegged into the ground about 15 to 20 cm below the tip, thus forming a ‘U’. During the season, the shoots grow and will produce roots where they are pegged down. To improve on the rooting success, the shoots can be wounded, or auxins applied. The stems are
usually allowed to grow for one to two seasons before cutting the rooted stem off and planting it under shade. For this method to be successful it is important that the substrate used for layering is kept moist, but not waterlogged at all times and that soil-borne diseases are avoided.

4) **Stooling or mound layering**

Stooling, or mound layering is done with plants that have been severely cut back (to between 2.5-5 cm above soil level) and that have the natural vigour to produce many strong coppice shoots. New shoots developing are continuously covered with moist soil, sawdust or other light substrate to about half their height. If they are covered too high, leaves may be covered leading to weakening of the shoot. At the end of the season, roots will have formed at the base of the shoots, which can then be cut off and planted as separate plants. Also with this method, the substrate has to be kept moist and free of pathogens.

To establish a stool bed, seedlings should be planted in rows wide enough to allow sufficient space for the mound or stool. 1-1.5 m apart has proved sufficient. They are allowed to establish for one growing season and then cut back to between 2-5 cm above ground to initiate the development of vigorous coppice shoots for rooting. It has been shown that girdling the newly developing shoots by forcing them to grow through a wire mesh can enhance the rooting success. Depending on the species, a 0.5 cm square mesh can be placed over the stump before the shoots develop. The shoots are then forced to grow through the mesh and are girdled as they thicken.
j) Micropropagation

Micropropagation or in-vitro propagation are terms used for procedures to propagate plants from plant cells, tissues or organs under aseptic conditions in a controlled artificial environment. The term ‘tissue culture’ is used for a wider aspect of culturing plant (and animal) cells, including for research that not necessarily aims at the production of a functional organism. The umbrella term for these procedures is ‘biotechnology’.

Many of the commercial nurseries, which use tissue culture techniques to produce propagules of various crops and trees, are found in developed countries and very few in developing countries. This is mainly due to the limited number of well-trained personnel in tissue culture technology, lack of awareness of the potential for micropropagation and inadequate capital to set up the facilities for micropropagation of important crop plants and forestry trees. However, micropropagation is an alternative and viable option for rapid multiplication of propagules to satisfy the high demand for crop and tree planting material by farmers.

2.1.6. Raising seedling from seed

A. Methods of raising seedlings

There are two general methods of raising seedlings in nursery site
a) Growing bare-root seedlings

Bare root seedlings are seedlings directly sown and grown on nursery beds without the need for containers such as polythene tubes (without a protective earth ball around the roots). Are cheaper to produce and plant. Used where the climate and sites are favorable and planting and transport reliable. Can be stored in the field for very short period of time only as are without ball of soil around the roots that contain moisture and nutrients and protect seedlings from desiccation. Disadvantages of bare root seedlings include unreliability; require favorable weather conditions, skilled manpower, & careful supervision for their successful field establishment.

Soil required for bare root seedlings: soil has to be suitable and cultivable like a vegetable garden to a depth of 30-40cm (as we are using the native soil). Avoid mixing of the topsoil layer with the inner one and keep the topsoil on the top of the bed. Seedlings in transplant beds are in rows of 20-25cm apart and 5-10 cm distance between seedlings (50 -100 seedlings/m²).

Transplanting: - seedlings for transplanting should be 6-8 cm tall, bigger than those pricked out into pots and having good root system (4-6cm length of taproot). Transplanting is done by preparing holes with dibble (or a ditch with a wedge spade) and inserting the plant without twisting the roots and filling the hole with soil from the seed bed which is gently compacted around the plants.

b) Growing potted seedlings

Are seedlings grown in containers such as polyethylene (plastic) tubes? Are expensive to rise in nurseries due to the need for purchasing the required amount and size of plastic tube, preparing soil mixtures, filling and stacking of pots as a result, and Time consuming. Difficult to handle seedlings due to the weight and volume of pots filled with soil, expensive to transport during planting. Can be stored in the field for longer periods of time before planting without damage to seedlings (provided that the seedlings are watered). Are reliable on all kinds of sites, especially on difficult soils and dry areas.

Potted seedling growth depends on the size and thickness of seedlings. The size of the tube varies according to: the species and the size to which the seedlings should be grown in the nursery. The most commonly used size in Ethiopia is 7- 10cm lay flat tubes, and length about 12-15cm. Thickness various between 0.0015 to 0.0005 inches or ( 0.0375 to 0.0625mm). The larger the pot
the thicker the tubing should be. Seedlings shouldn’t grow > 45 cm in height using such tubes and are used to raise seedlings of cypress, pines, eucalyptus etc. Large 10cm lay flat tubes are preferable for raising tall and strong plants such as, olea, podocarpus. Generally, best for indigenous hard woods destined for planting in natural forests and also recommended for planting in dry areas as these larger sized pots can store large quantity of water in root zones which increase the chance of Survival of seedlings after planting.

B. Seed bed and transplanting beds
Bed is elongated strip of prepared soil in which seed sowing and establishment of seedlings is made. Beds are constructed after the area is leveled and once road and irrigation systems have been installed (See the procedures). Bed construction differs from one method to another. Seedlings could be either bare-rooted or containerized. Beds are generally divided into seedbed or transplanting bed.

Seedbeds: are elongated strip of prepared soil in which seeds are sown and seedlings are raised. Should be 1m wide to reach the center of bed from either sides of the bed. Length should not be longer than 20m. Seedbed soil should be light, to avoid heavy clay soil, porous textured so that soil allows good root penetration and easy for lifting.

Transplant beds: elongated strip of prepared soil or leveled ground in which seedlings are moved from one bed (seed bed) to another to promote additional growth.
a) Nursery soil mixture and potting.

For the production of bare-root seedlings native (available) soil is used. But, usually, additives such as sand and organic matter are added to it.

For raising seedlings by using pots: soil ingredients/component mixtures/ for filling of pots are brought from outside the nursery. The proportion/ratio/ of these different soil components to be used varies from place to place, the species to be raised, and the availability of different soil ingredients.

The characteristics (qualities) that make up good nursery soils are: - good drainage, having satisfactory contents of essential nutrients, good organic matter content to retain moisture, sufficient adhesion to form a soil cylinder (keeps the soil in pots without falling through the bottom), correct acidity, mycorrhiza. Many soil types lack these qualities except, humus rich forest topsoil’s and compost that have these desirable characteristics than other soils.

A potting soil can be a mixture of local soil, compost, forest soil and gravel or sand.

1) The local soil: easily available in large amount hence, called basic soil.
2) Gravel and/ or loamy sand improves drainage, good root penetration
3) Cattle manure or compost or fertilizer: provides organic matter to improve moisture holding capacity and also nutrients.
4) Forest soil: - Used to improve water-holding capacity and provide nutrients.
5) Soil from pine plantation: required for raising pine species to acquire mycorrhiza that serves for the growth of pines.

6) Clay: - helps the soil bound round the roots and form soil cylinder (improves adhesion)

As forest soil is normally not readily available at the desired quantities under most circumstances the potting soil is therefore a, mixture of local soils and compost

i. Determining Quantities of Soil Components Required:

Once the ratio of different soil components are determined, the required quantities of forest soil, sand soil, compost, local and others can be calculated. Parameters required for calculating each component are:- Container size (dimensions); Number of seedlings to be produced. The proportion (ratio) of each component in the total soil mixture.

See example below

Potting - is the filling of pots with soil.

The pot size to be used varies depending on the tree species to be raised, from place to place, plantings site & to some extent means of propagation and seed size.

b) Potting procedures

1) First bring all the required quantities of each soil component.
2) Screen each components thoroughly using sieves
3) Mix the components thoroughly and store them nearer to the potting shed.
4) Cut the plastic tubes in to individual containers of the required size /length/ 12-15 cm length.
5) The soil mixture is then moistened to become humid but not wet.
6) Fill the container using a hands or funnel (when filling the lower 1/3 portion of the pot should be compacted rather firmly to keep the soil from falling out easily. Then, the upper 2/3 portion of the pot compacted gently as the roots develops more easily.
7) Avoid any air pockets inside the pot during filling as this can hamper root development.

C. Sowing Methods

a) Direct sowing into pots versus seedbed sowing
Initially seeds of most species used to be sown into seedbeds followed by transplanting into beds or containers. But nowadays, there is a tendency towards more and more direct sowing into pots to eliminate the labour consuming operations.

1) Seedbed sowing is recommended,
2) If seeds are expensive or scarce
3) Germination percent and period is not known,
4) If seed takes long time to germinate.
5) Seeds are too small
6) Direct sowing on to pots can be done where:
7) Germination percent is known & to be fairly high.
8) Germination period is short.
9) Transplanting would cause damage or death to seedlings (a case in very dry areas)
10) The species develops a long sensitive taproot.
11) If there is a shortage of skilled workers to do the transplanting.

Direct sowing onto pots leads to wastage of pots if germination takes a long time, as the plastic tubes start to disintegrating and leaching of nutrient in the soils of the pots, owing to many weeks of watering.

i. Time of sowing
Sow seeds timely to acquire seedlings of the right size (Shoot length) (25cm - 40cm length at the time of planting). Adjust the time of sowing with the period of rainy season. Recommended sowing dates for different species is presented in the following table. Planting is done in June. The numbers in the brackets indicate the number of months required for seedlings to stay in the nursery.

Table: Showing sowing dates for different species in Ethiopia

<table>
<thead>
<tr>
<th>Species</th>
<th>Sowing Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia cyanophylla, A. meairnsii, A. decurrens</td>
<td>Jan - March (4-6)</td>
</tr>
<tr>
<td>A. Melanoxyylon. Apyvanina A. Saligna</td>
<td>Jan - March (4-6)</td>
</tr>
<tr>
<td>Albizzia lebbeck</td>
<td>Jan - March (4-6)</td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td>Jan - March (4-6)</td>
</tr>
<tr>
<td>Casuarina equisetifolia Cumppinghamiana</td>
<td>Sept-Oct (8-9)</td>
</tr>
<tr>
<td>Cordia Africana</td>
<td>Nov-Jan (4-6)</td>
</tr>
</tbody>
</table>
Croton macrostachys  Jan - Feb (4-5)
Cupressus lusitanica  Oct - Nov (7-8)
Eckebergia rueppeliana  Oct-dec. (7-9)
Eucalyptus camaldulensis  Jan - Feb (4-5)
E. Globules  Feb- March (3-4)
E. Grandis. E. Saligna  Feb - March (3-4)
Grevillea robusta  Jan - March (3-4)
Hagenia abyssinica  Oct - Dec (7-9)
Juniperus procera  June - July (12-15)
Melia azedarachta  Jan - March (4-6)
Olea hoesteterh  Sep- Nov (8-10)
Parkinsonia aculeate  Oct - Dec (7-9)
Pinus patula  Sept - Nov (8 - 9)
P. radiate  Nov - Dec(6-7)
Pithecolobiom dulce  Jan - March (4-6)
podocarpus gracilior  April - June (8-15)
prosopis juliflora  Jan - March (4-6)
pygeum afiricana  Sep - Nov (8-10)
Schinus molle  Jun - March (4-6)

ii. Density of sowing

Larger seeds should be sown at a lower density of about 800-1500m²

For smaller seeds (like eucalyptus, pines and cypresses) sowing density can be decided so as to obtain 2000 seedlings/m² of the seedbed. Too low density of sowing leads to wastage of seedbed area (not economical); Too dense sowing- increases risk of fungus diseases in the nursery, Sever competition among seedlings for nutrient, water, light and others. Parameters required for calculating optimal sowing are:-

- Number of seeds/kg,
- Germination percentage
- Purity percentages. These are needed to determine the numbers of viable seeds/kg.
E.g. Pinus patula has 135,000 seeds /kg and a germination rate of 85%. How much seed should be sown to each square meter to obtain a density of 2000 seedlings / m²?

Solution; - each kg of seed produces \((\frac{85}{100} \times 135,000\) seedlings = 114,750 seedlings assume 100% purity.  
\[ \frac{114,750 \times 1000 g}{2000} = x \]  
\[ 2000 \times 1000 g = 17.4g/m² \]  
\[ 114,750 \times 17.4g \text{ seed is needed for 1 m}^2 \text{ in order to obtain 2000 seedlings of Pinus patula.} \]

b) Sowing Techniques

Three major techniques of sowing which are:

1) Broad cast sowing into seed

Is a method of sowing in which seeds are distributed across the seedbed using hands. Is the most common method used recently? Used for sowing seeds of all sizes, but best suited to smaller seeds.

Procedures: Level beds for sowing. Water beds the day before sowing to attain the right moisture condition and apply broadcast sowing as evenly as possible. Tree species having too smaller seeds are usually difficult to sow them evenly, as a result mixing the seed; with an equal or double amount of fine sand helps to achieve an even seed sowing. Cover seeds with seedbed soil mixture or sand at a depth of twice the thickness of the seed. Avoid any air pockets between the seeds and soils by pressing the soil gently.

2) Drill Method

Is sowing method in which seeds are planted in rows with a seed-drilling implement. Has been practical mainly with species having large seeds. The depth of the drill should be equivalent to the size of the seed (e.g. 2-3 mm for juniperus and 2mm for pinus patula). Distance between drills is usually about 10 cm.

A wooden batten, 1m*1cm*3-5cm is needed to press drills on to beds. The seeds are placed into drills at bottom & drills are covered with seedbed soil mixture and followed by watering the bed.

c) Direct sowing onto polyethylene tubes
Is placing of seeds in the pots at the specific depth and density. Used commonly in recent period. Advantages helps to eliminate the time consuming operation of transplanting that may cause a slow growth and, even death of seedlings some times. Place seeds in the middle of the pot followed by pressing down and covering with soil. For large seeds, a hole is first pressed into the soil by a pricking stick and then seeds are placed into it followed by covering them with soil. Avoid the formation of air pockets during sowing. The no. of seeds to be sown into individual containers is related to germination percentage. E.g. If germination is between 35-50%, 3-5 seeds If the germination percentage of a seed lot is > 80% sow 1-3 seeds/pot

d) Care and conditioning of seedlings
If conditioning is not right or care is not taken viable seeds either will not germinate or will be lost even after seedlings have emerged. New seedlings may also have to survive hailstorm, scorching sun and temperature. Hence, Certain steps can be taken to nurture seedlings through this period and ensure their vigor.

1) Mulching
Is any artificial modification of the soil surface. In nursery operations, mulching means covering the bed surface with a layer of organic materials. The primary purposes are: - To conserve soil moisture by reducing evaporation from the oil & protects it against sun hence, lowers the soil temperature
Protects the soil against heavy rains that can wash the seeds which are sown. Also minimizes the risk of exposing the seeds to birds and rodents.
Mulching helps to reduce both the frequency and amount of watering needed in areas where watering is necessary throughout the year. To be effective a, layer of mulching should be 1-2cm thick.
Materials for Mulching: - grass, rice straw, rice husk, compost, and partly decomposed forest litters or saw dust are commonly utilized.
Avoid use of mulch to beds in rainy areas as this can reduce aeration and risk of damping off would be increased.

2) Watering
i. Have a good supply of water for the well growth of seedling.
ii. Avoid too much watering as it is harmful.
iii. Use clean water with pH value ranging from 5.5 to 6.5.
iv. Keep newly sown containers seed trays or nursery beds continually moist though not soaking wet.

No fixed rule about the intervals between watering and quantity of water required, as this varies with Species, Soil conditions, Age of plants, Weather condition, etc.

A very approximate recommendation for total amount of watering per day is equivalent to 8-mm rainfall. This means 8 liters of water/m² of seedbed.

Frequency of watering:

Should be done frequently (at least twice a day in small quantities). E.g. if watering is done twice a day, four liters/m² should be applied in each watering.

Time of watering:

Should be done early the morning (before 10.00 a.m. & in the afternoon after 4:00 p.m), for efficient utilization of water sprayed on to them without being lost. Avoid too heavy watering, as this causes pudding of soil & poor aeration, which creates favorable condition to damping off-fungi. Find out the best possible watering regime for your area. Fine-hose watering cans must be used in watering of seedbeds without grass mulch. If not available, try to use grass much. Water seedlings immediately after transplanting (2-4 times a day).

3) **Shading**

Needed in early stages of seedling development from sowing to sometime after pricking out, as seedlings are sensitive to full sun light, high temperature, rain, and dry winds. Usually apply shading mat, immediately after removing the mulch. Benefits of Shade: Reduce soil temperature; Minimizes evapo-transpiration rate and damage of seedlings by direct sunshine.

The need for shading/shading intensity/ differs according to Species, Stages of seedling development,

Weather condition and Location of the nursery. Full and dense shade on seedbeds gives best results with most species. Full shade for seedlings should be given during the most delicate growth stages, i.e. during and shortly after transplanting. When seedlings are resistant, reduce shading gradually from all day to around mid-day and later to none at all, as light is essential for photosynthesis. For the last months in the nursery seedlings should be exposed to full sunlight.
i. Shade construction:

Can be constructed as a temporarily or as permanent installation.

Build poles or wooden posts at 2 m interval connected at the top by longitudinal and cross beams, then shading mats or screens can be placed on top of the scaffolding.

Simple shade made of forked sticks (60-100 cm from the ground) can be used for support of shades, in private nurseries. Too low shades make watering difficult.

ii. Orientation of shade

In order to obtain the maximum effect of shades, the beds should be oriented in East - West direction. When the sun is north of the equator (April – Sept) the shades should be sloping down to the north and during the rest of the year, which is the main nursery period with most species in Ethiopia, the shades should be sloping down towards the South. Sloping shades have an advantage over horizontal shades in that it avoids formation of pools of rain water which may leak & cause some erosion in the seed bed below washing away both seedlings and soil.

Materials: - like, elephant grass mat, bamboo split matting shads; grass shading or broken leaves can be applied for making shads. Refer part VII, number 15.3.3 (a-i), UGIS, 2015

2.1.7. Mycorrizal inoculation

Mycorrhiza is a symbiotic association of non-pathogenic fungi and the roots of forest trees. In conifer species, the fungus forms a mantle over the absorbing rootlets. The fungus draws carbohydrates from the tree (serves as primary energy source) while the tree is provided with water and essential minerals, which are not ordinarily available to the tree.
A. Benefits of mycorrhizal

About 85% of plants are known to host mycorrhizal fungi. It services as biofertilizer: plant nutrient supply through mycorrhizal root, a fine network of fungus threads/hyphae/ explores and extracts nutrients from a volume of soil far beyond the bounds of the roots capability.; as biocontrol- antagonism of parasitic organism: fungus, bacteria, nematodes; to supply water special in drier area when arbuscular mycorrhizal is used.

For humans it is provide valuable food resource e.g. chanterelles, pine mushrooms, morels, king, boletus, desert truffle (Terfezia ssp.) and used as economic gain, medicinal uses; aesthetic values fungi diversity as a bio-indicator of environmental quality.

Minimize plant competition and maintaining abundance and diversity plants hosting linked by the same mycelia share nutrients; movement of carbon from the plant to the fungus, and for movement between plants linked by mycelia; Mycorrhizal association maintain plant of diversity in tropical natural forest.

Ecosystem rehabilitation: absence of native mycorrhizas will not all quick restoration of degraded ecosystems. Inoculation grasses and trees with armuscular mycorrhiza has shown better survival and rehabilitation in the tropic. Also heavy metals (such as Zn, Cu, Mn, Ni, Cr cronium) is enhanced by their colonisation by mycorrhizal fungi. Ect-omycoriza plants in alkaline soils access limiting nutrients such as P and Zn.

In soil: mycorrhizas transport, store, release and cycle nutrients; improve soil structure: Arbuscular mycorriza fungi increase the formation of soil aggregates

Mycorrizalae inoculation at nursery level is a necessity to get the above mentioned benefit. Moreover, some plants are obligate host and cannot survive and grow in the absence of mycorrhizal association.

For example, Pinus patula can’t survive without ectomycorrhiza. For most of pine species we have to inoculate young seedlings by taking soil from existing planation.

Similarly, common agricultural crop and trees (coffee, citrus, avocado, mango, and most legume trees) are obligate host of arbuscular mycorrhizal fungi and inoculation is necessity.

2.1.8. Transplanting (“Pricking out”)
Is a practice of moving seedlings from one bed to another to promote additional growth or it is the lifting of seedlings from their original seedbed to plant on to another location in the nursery (transplant bed or from pot to pot). Such seedlings called “Transplant”. It is a crucial stage in the life of a plant as it always causes a shock to the seedlings even when done carefully. Bad transplanting easily kills the seedling. Size of seedlings for transplanting: conifers can be transplanted as they attain a “Match stick” size after seed germination. Broad-leaved seedlings should also be transplanted soon after germination. Acacia and other legumes are transplanted when the first leaves appear after complete unfolding of cotyledons. Watering the empty pots or beds lightly for a couple of days before transplanting, promotes the germination of seeds of weeds which will be removed soon.

A. Care to be taken for transplanting
Moisten the pots/beds prior to transplanting (should not be too wet or dry at the time of transplanting. Use a small tin filled with a mixture of soil and water to keep the lifted seedlings for transplanting. Use a wooden sharpened stick about the size and shape of a pencil for digging a hole, having a size to cover the young seedlings up to the root collar. Seedlings should be handled by the seed coat or the leaves but never by the stem or root, which are easily burned; thus creating opening entry to damping-off fungi. Cut the roots of seedlings using knife or finger mails, which are rather long.

a) Procedures for transplanting into pots
1) Erect a large portable shade.
2) Water the seedbed to become moistens.
3) The transplanters sit on small low stool to work in pairs on opposite sides of the bed.
4) Make a hole with the dibble in the center of each pot.
5) Place carefully the roots of the seedlings in the hole without twisting them and soil is push towards the root with the dibble to make sure no air space is left around the root.
6) Seedlings are placed at the same depth or slightly deeper than they were in the seedbed.
7) Firm the soil around the seedlings gently and smoothed with the fingers so that no depression is formed around the stem.
2.1.9. Weeding

A weed is a plant growing where it is not wanted. Should be removed in time as they compete with the seedlings for nutrients, water & light which will suppress the seedlings. They also harbor insects or diseases.

A. Propagation of weeds
Can be propagated either by seeds or by underground stems and rhizomes, the latter being more difficult to eradicate. Carryout weeding when the soil is just moist, and not too wet or dry. Weed dissemination: Weeds or rhizomes enter a nursery with; Irrigation water; the soils brought for filling pots; Compost & manure or by wind,

a) Weed Prevention techniques
Establishing hedge around the nursery or compartment will prevent weed infestation by wind. Filtering irrigation water passing through weed infested areas in open canals using a fine wire screen before distribution. Potting soil and compost may be sterilized to kill all weeds. Rhizome infested compartments must be repeatedly worked to remove all rhizomes before nursery beds are laid out. Water beds and containers for some days before sowing of the tree seeds so as to facilitate the germination of a weed seeds and to eradicate them. Adjacent grasslands should be regularly cut.

b) Weed Elimination techniques
1) Hand weeding
should be limited to plant containers or germination beds were the weeds cannot be reached by tools without disturbing or damaging the seedlings. weeding hoes, cultivators etc. may be used for weeding of plants in widely spaced traditional beds,

2) Mechanical weeding:
Done by motor cultivators, tillers, & rotary hoes attached to a tractor is limited to large level nurseries producing bare rooted plant stocks.
Chemical weed control: Done by weed killing chemicals called herbicides. Widely used in agriculture and land clearing during planting. Should be restricted to large nurseries raising mainly conifer seedlings & to nurseries where labour is expensive or not available.
Chemical can have a harmful effect on broad-leaved tree species. Non-selective herbicides are toxic to all kinds of plants and they are used for weed control on paths, along fence line & around buildings. Selective herbicides destroy certain species selectively but cause little or no injury to others. Herbicides like 2.4.D and 2.4.5.T kill broad-leaved weeds but not grass and conifers. Chemicals like formaldehyde, methyl bromide used to sterilize bed soils to kill weed seeds effectively. Obey the directions given by the manufacturers in applying chemicals so as to prevent damage of seedlings & the user. Refer part VII, number 15.3.3(b), UGIS of 2015

2.1.10. Root Pruning

A. Root Pruning
Involves cutting of the taproot, in some cases also of lateral roots, to encourage the development of a fibrous compact root system.

a) Benefits of Root Pruning
   1) Gives the seedlings the best possible start in the plantation site because of a well-developed fibrous root system.
   2) Helps to control depth of root penetration and makes lifting of seedlings easier and less harmful.
   3) Helps the seedlings to have a balanced root-shoot ratio.
   4) Helps the seedling to have an adequate root collar diameter (because of the slowdown of the top growth)
   5) Un-pruned roots will create problem at the time of lifting and planting, as a large part of the root system is cut off during lifting & the seedlings will suffer from a serious shock during planting.

b) Methods of root Pruning
Can be done in several ways:

1) Pruning with knife or secateurs
Most common method with potted seedlings. Each pot is lifted up & the protruding roots are snipped off. Consume time as a single person can only prune 500 seedlings a day. It is good to
leave some 30cm of the storage bed without pots at one end, so that pruned pot can easily be lifted to the other side as the work proceeds.

2) **Root wrenching (Shocking)**

Pots are only lifted off the ground to snip or pull roots which has grown in to the ground. Much faster than knife pruning and the operation can be combined with weeding or cultivation. Not sufficient to use it alone hence, roots should be cut with knife or secateurs every 4-6 weeks between root wrenching.

c) **Pruning with piano wire:**

Piano wire about 2m long with wooden handles at both ends is passed under the reverting board frame. Applied to potted seedlings, which are kept in raised beds framed with reverting boards, and to bare rooted seedlings in Swaziland beds. A 16, 18, 20 or 22 gauge (22 is the thinnest) used.

d) **Frequency of root pruning**

Frequency of root pruning depends on: - The growth rate of seedlings, Species and environmental condition of the nursery. Weekly pruning is recommended for fast growing seedlings (ex eucalyptus). With pines and cypress, the in interval between prunings is about 2 weeks.

e) **Care of seedlings at pruning**

Best to do root pruning on a dull, cloudy or during the cool hours of the day. A clean cut with a sharp blade favor proper healing of the pruned roots. Immediately before and after root pruning the container bed should be watered thoroughly to soften. Some species like Eucalyptus and other need to be put under shade for couple of days to prevent wilting after pruning.

f) **Shifting and caring**

It is arranging seedlings according to their size or their height growth to improve the growing condition and to give seedlings equal chance of using sun light for photosynthesis.
Quality Control (Grading)
The quality of nursery stock depends greatly on the way it is graded, packaged, transported and stored. Grading involves eliminating inferior seedlings or batches of stocks to improve stock quality in satisfying the management objectives at planting sites. We look for quality seedlings to: maximize performance at planting sites. Sometimes compensate inadequate site preparation. Avoids the need for replanting b/s of planting failures. Quality seedlings are those which: have balanced root-shoot ratio; Have dense fibrous, compact root system; Have better growth of root collar diameter; Seedlings with the right size & able to establish quickly in the field; Have good and healthy appearance. It is good to determine quality by trail after planting. The following indices’ could guide us.

Morphological index (MI)
MI= height \times \text{diameter at root collar} \times \text{root/shoot ratio}
Applied as an average value based on sample of population root/shoot ratio is obtained by weighing the separate parts

Sturdiness Index (SI)
SI= \text{diameter at root collar} \times \text{height}
Applied to individual plants are then grouped according to height class

Lifting and culling
Culling is rejecting of all poor quality seedlings that are not satisfying the requirements. It is important in quality control. Only seedlings rejected on the basis of size can be retained in the nursery for latter check. Plants rejected in the second culling because of insufficient quality (defects) will be destroyed. Culling is done in connection with lifting of seedlings for transport to the planting site.

2.1.11. Hardening off
In a nursery, seedlings are kept under favorable conditions (are growing under nearly ideal conditions with good moisture and nutrient conditions) hence are, very vigorous but often succulent, not likely to be able to with stand the often harsh conditions in the field after planting.
Planting is always a shock for seedlings, but this will be less if seedlings are sturdy, semi-woody and prepared to face the adverse conditions in the field (especially lack of water, exposure to full sunlight and cutoff fertilizer application). As a result seedlings in the nursery are commonly exposed to harsher environmental conditions so as to survive well under field conditions. This common nursery practice of gradually imposing harsher conditions to the stocks starting a few weeks before planting is called hardening off.

In hardening off 4 - 6 weeks before planting, watering is reduced progressively down about 3/4 – 1/2 of the normal quantity. Water is applied less frequently. Intensity of hardening off: Depends on planting conditions and if planting areas are dry, it is sometimes advisable to reduce watering to the point where seedlings are almost wilting. Apply normal watering regime some days (about one week) before planting. Immediately before planting plants are watered thoroughly. Hardened seedlings have firm lignified, sturdy, well develop crown with many fine, fibrous lateral roots. The root/shoot ratio is well balanced.

2.1.12. Fertilization of Nursery Soil

It is always necessary to replace the lost nutrients (with bare root seedlings). However, soil fertility is only one of a number of factors influencing stock quality. Fertile nursery soil does not compensate for poor practice.

A. Plant nutrient and deficiency Symptoms

Plant nutrients are chemical elements that are essential for life process in the plant organism like photosynthesis, cell division, flowering, fruiting etc. Inadequate mineral nutrition’s usually results in reduced seedling growth before any characteristic deficiency symptoms become evident. Symptoms are rather similar for deficiencies of different nutrients; hence, determining the particular nutrient causing the deficiency is seldom possible without supporting evidence (e.g. tissue analysis). Nutrient deficiency will result in stunted seedlings with discolored leaves (Symptoms should not be mistaken for diseases). According to the quantity required by plants the chemical elements can be grouped in to Primary /macro/ nutrients (nitrogen, phosphorous, potassium); Secondary nutrients (Calcium, Magnesium, Sulfur) and Micronutrients or trace elements (iron, copper, zinc etc.).
Inorganic nutrient should be used to supplement organic fertilizer. The following symptoms may hint at nutrient deficiencies

- **Nitrogen**: forms part of the chlorophyll of protein and nucleic acid. Has a strong influence on vegetative growth. Nitrogen deficiency symptoms include that plants become dwarfed and stunted with leaves of light green or yellowish (without darker veins). Too much available N in the soil delays the maturing and hardening of the tissues.
- **Phosphorus**: needed for flowering and fruiting, no seeds development without this element. Encourages root growth and increases the general resistance of the plant against diseases. Deficiency symptoms: results in gray-green to bluish-green spots and blotches on the leaves of broad-leaved species. The needless conifer remains short and is of red-violet colour.
- **Potassium**: K regulates the water content of the plant tissues and increases the resistance against drought. Deficiency of potassium results in dry-looking scorched seedlings, pine needles start drying from the tip.
- **Calcium**: is important for the moderation of acidic soil reaction. It results acidic condition which intern makes many nutrients except iron and manganese unavailable to plants. Too much calcium results in an alkaline reaction (Also unfavorable, because it will cause a shortage of phosphorous and many trace elements.
- **Magnesium**: is a central component of chlorophyll. Mg deficiencies symptoms are yellow spots all over the leaves along the veins. Coniferous species turn yellowish from the tips.

### 2.2.13. Nursery hygiene

Healthy plants are the goal of every nursery manager. This is not restricted to research nurseries rather, applies to nurseries of all sizes and levels of sophistication. Nursery hygiene does not necessarily mean using expensive or toxic chemicals; we can achieve a healthy nursery with ecologically sound management system. Traditionally, there have been two basic approaches to nursery health: **preventive actions**, which include balanced fertilizers, use of resistant species or cultivars, timely hardening of plants, cleanliness in the whole nursery, and training of staff, and **curative actions**, which include the use of pesticides, heat, biological control or physical
measures (e.g. cutting out of diseased parts). From these two approaches, integrated pest management has evolved, combining ‘preventive’ measures with ‘curative’ methods, and using chemical, biological and cultural control. It is neither practical nor wholly desirable to attempt total elimination of pests, as many beneficial organisms are destroyed in such efforts, and a lack of beneficial organisms can lead to an explosive recolonization of the nursery beds with pests.

A. Pathogens

Pathogens are a plant disease that hinders plant growth. Most of plant diseases are fungal which cause damping-off (Figure1) particularly Pythium, Rhizoctonia and Phytophthora. The symptom is the development of a zone of weakness at a point on the young seedlings where the stem and the root meet. The seedling rapidly loses turgidity, bends over and soon dies. It can occur on seed before germination, or on young seedlings. Sometimes this can happen without any fungi present, for example, with high temperatures of the propagation medium. There is often (but not always) damage to the plant beneath the soil surface as well. The reason for symptoms appearing at the soil surface are not well understood but might be related to the point where the plants start photosynthesizing or where aerobic/anaerobic conditions are conducive to the more virulent stages of the life cycle of the fungus. Pathogens which cause damping-off, particularly Pythium, Rhizoctonia and Phytophthora, can be spread in the irrigation water, high plant density, overwatering and heavy shade favor the spread of the disease (Jaenicke, 1999).

![Figure 8: Damping off at the roots of seedlings at nursery site](image-url)
Heavy watering, particularly in the afternoon and evening hours encourages the disease so that as a first step, watering should be reduced to a minimum and only in the mornings. As a preventive measure, the seedbed should be watered once a week during pre- and post-germination with a solution of a copper based fungicide. To control attacks of the fungus, the fungicide should be applied every three days until brought under control or as directed by the particular supplier. In soluble form it is best applied with a knapsack sprayer (Hall, 2003).

b) Insect Pest control

Pests affect both (morphological and physiological characteristics) of forest nursery seedlings. Determining the cause of this quantity and quality deterioration (abnormality) requires a thorough examination of both individual seedlings and the nursery in general. In plant condition observation (foliage, stems and roots of seedlings), be cautious what a healthy plant look like. The foliage is the best place to begin the examination because it is the first and most obvious portion of the seedling to show visible effects of abnormal conditions. Once you established a healthy standard for your nursery seedlings, abnormalities can easily be detected with the symptoms in progress. Pockets of affected seedlings with a development of symptoms from the center outward, for example, may indicate disease or insect infestation that is spreading. Seedling damage in depressions may indicate problems such as chemical buildup, poor drainage, or pests that are favored by poor drainage.

Protection against grasshoppers, slugs and other leaf eating insects will sometimes be necessary. A number of formulations are available on the market, and distributors should be consulted on the most suitable chemical for the particular problem. A list of chemicals available locally and sources is provided at Appendix 4. Remember that temporary control can be effected by isolating the plant(s) until spraying is done.

c) Weed control

Weeds compete with the seedlings for nutrients, water and light. If they are not removed in time, this competition will suppress the young plants because the weeds are usually more vigorous and grow at a faster rate. The most troublesome are grasses or dicotyledonous plants that grow from a root stock. If such a weed is cut off at the ground level, it will sprout again and continue to grow from the carbohydrates stored in its root tissue hence the need to remove the whole plant.
As much as possible one should prevent the presence and dispersal of weed seeds in the nursery. Most weeds produce large quantities of seed which are easily transported by water, wind and also brought in by introduced top soil, chicken litter and farm yard manure. No weeds should therefore be allowed to flower and fruit along paths and roadways or unused land in the nursery. Grassy areas should be regularly cut and trimmed. A thick hedge around the nursery helps keep out weed seeds that are otherwise brought in by wind. Since it is more difficult to eradicate weeds after they have invaded seedlings growing in containers and in transplant beds, both the potting soil and the pre-filled containers may be watered in advance so that the germinated weeds can be removed in advance of transplanting. For this purpose, containers should be filled up to 4 weeks in advance of transplanting or direct sowing operations if weed free potting soil is not available.
PART THREE
POLICY, LEGAL FRAMEWORKS AND CAPACITY REQUIREMENTS


3.1.1 Manpower Requirement

A. BSc in Urban forestry and greenery, plant science or forester = 1
B. Forman Diploma =1
C. Daily labor for all routine activities through the year, 40 person per day X 22 days X 12 Months = 10560 persons

3.1.2 Logistics and Finance Requirement

A. Tools and equipment

<table>
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<tr>
<th>No</th>
<th>Items</th>
<th>Unit</th>
<th>Quality</th>
<th>Unit price</th>
<th>Total price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheel Barrow</td>
<td>No</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Pick Axe</td>
<td>&quot;</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Spade</td>
<td>&quot;</td>
<td>15</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Hoe</td>
<td>&quot;</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rake 12 Finger</td>
<td>&quot;</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Machete</td>
<td>&quot;</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shovel 3-finger</td>
<td>&quot;</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Axe (3kg. china made)</td>
<td>&quot;</td>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>9</td>
<td>Watering Can - plastic</td>
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<td>15</td>
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<tr>
<td>10</td>
<td>Root pruning Scissors</td>
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<tr>
<td>11</td>
<td>Hedge scissors</td>
<td>&quot;</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Bow Saw</td>
<td>&quot;</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bow Saw blade</td>
<td>&quot;</td>
<td>10</td>
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<tr>
<td>14</td>
<td>Measuring Tape 50cm</td>
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<td></td>
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<tr>
<td>15</td>
<td>Measuring Tape 30cm</td>
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<tr>
<td>16</td>
<td>Bucket - plastic</td>
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<td>10</td>
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</tr>
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</table>
### B. Construction

<table>
<thead>
<tr>
<th>s.n</th>
<th>Description</th>
<th>Cost if any</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Office and store (15m X 6m) but for office (4m X6m); for tools and equipment store (6m X6m); for seed store (5m X 6m)</td>
<td>657500 Birr to the complete the work. This cost is simply an indication</td>
</tr>
<tr>
<td>2</td>
<td>Toilet (6m X 2m) two rooms</td>
<td>123000 Birr</td>
</tr>
<tr>
<td>3</td>
<td>Shelter (6m X12m)</td>
<td>90000 Birr</td>
</tr>
<tr>
<td>4</td>
<td>Three office tables</td>
<td>8000 Birr</td>
</tr>
<tr>
<td>5</td>
<td>Two benches</td>
<td>For office only</td>
</tr>
<tr>
<td>6</td>
<td>Shelf for store mainly for seed store 54m²</td>
<td>62000 Birr</td>
</tr>
</tbody>
</table>

### C. Paths in nursery

Concert path construction is not recommended in nursery unless the site is waterlogged. In this case nine paths from perpendicular to each other could be considered. It is assumed that cost for 1 m² of concret path to be 120-170Birr. The total length of path is 181m² (9path with length of 100m Vs 9 paths with length 91meter). The total cost ranges from 21720-30770Birr
3.1.3. Systems Requirement

For public nursery the municipality will be responsible to raise seedling for different GIs development or maintenance. In this case nursery management will be under legal institution. For private nursery participatory planning and management is required. In all cases the nursery activity has to be in line with national, regional and local government plans.

3.1.4. Institutional Arrangement

Institutional arrangement has to be linked the entire instutional arrangement for GI development for each urban center.

3.1.5. Information Technology

The type and extent of communication for nursery promotion depends on availability of resources. Promotion through through internet like operational guide line, quality seedling produce marketing.
Effective date
This Ethiopia national Manual for Manual for Private Garden Establishment and Management shall be entered in to force as of January, 2016.

H.E Mekuria Haile
Minister for Ministry of Urban Development & Housi
References


Appendix 1. Nursery equipment’s and tools. Refer part VII, number15.3.3(i) , UGIS of 2015  

Figure 6. some hand tools and nursery operational equipment