TRAINING MANUAL FOR NURSERY CERTIFICATION
TOOL FOR NURSERY INSPECTORS

KEFRI 2021

Contents

1.0 INTRODUCTION

Forests and trees on farm play a critical in provision of goods and services and it is a major source of livelihoods for many communities. Successful forest conservation and regeneration efforts require the use of reproductive materials that meet appropriate genetic, morphological and physiological quality standards. However, research and field experiences invariably show that most of the seedlings planted out are of low quality leading high mortality rates when out planted. Seedling quality is a major factor that determines the success of tree farming and reforestation. The survival of trees, growth performance, length of rotation period and volume and quality of timber that can be harvested are greatly influenced by the quality of seedlings used. Seedling quality refers to genetic and physical characteristics of the seedling. Genetic quality relates to the genetic characteristics of the mother tree, while physical quality refers to the physical condition of the seedling as it is raised in the nursery. A high quality planting stock, is that which is: grown from germplasm collected from selected sources; healthy and with dark green leaves; having sturdy stems and with relatively large collar diameter; having root systems that are free from deformities and are dense with many root hair tips; having balanced root and shoot mass; and fully hardened, accustomed to full sunlight and reduced water and fertilizer. Certification of tree nurseries will address problems of low quality, low vigor and poor health that is associated with high field mortality at out-planting. The main purpose of tree nursery certification is to ensure production of quality and healthy planting materials for quality products and maintain environmental health.

1.1 What is a training manual?

A training manual is a book or booklet of instructions, designed to improve the quality of a performed task. A training manual may be particularly useful as:

- an introduction to subject matter prior to training
- an outline to be followed during training
- a reference to subject matter after training
- a general reference document

A training manual may form an important part of a formal training programme. For example, it may help ensure consistency in presentation of content. It may also ensure that all training

information on skills, processes, and other information necessary to perform tasks is together in one place and standardized.

1.2 Purpose of this training manual?

The purpose of this training manual is to equip nursery inspectors with the right skills on seed quality and healthy for certification. It is expected that all nursery inspectors undergo a training on all aspects that lead to production of high quality seedlings.

2.0 GENERAL TAXONOMY

2.1 Introduction to plant identification

Plant identification is very important especially in the nursery as it helps one to know the species they are dealing with and their requirements. There are several ways one can identify a plant, these include; keys, books, pictures, asking experts and comparing the plant samples with herbarium specimens. Inorder to identify a plant, one needs to recognize characteristics like size, form, leaf shape, flower colour, or fragrance. It is always good to use a fertile specimen (with flower and or fruit) in identification. Since seedlings lack flowers and fruits, leaves are the most important parts in their identification. Leaf characters such as shape, arrangement, form, venation, margin, lobes, thickness and fragrance.

3.0 NURSERY TECHNIQUES

3.1 Introduction

Nursery practices are an important and essential part of forestry development. This is because production of quality seedlings and their subsequent survival in the field depends very much on the nursery practices. This is particularly so with on farm small scale nurseries where the managers (farmers) have not undergone any training on nursery techniques. This therefore poses a special problem to the farmers and those bestowed with the responsibility of carrying out forestry extension on the farmlands. In addition there are a number of tree species that farmers could like to raise because of their economic value or importance in agroforestry programmes

requiring that each of these has a special technique in the nursery. It is also true that small scale nurseries sometimes deal with a wide variety of tree species most of which very little information on their nursery requirements is available. Well managed nurseries guarantee seedling quality and this has a strong bearing on either the quality of seedlings at the nursery level or on survival in the field. This to some extent complicates the art of seedling production at the nursery level. For high quality seedlings that will not only survive well but also give superior quality wood products, some technical aspects that require special attention include: potting media preparation, nature of pots and sizes, timing, transplanting, shading, watering, root pruning and hardening up.

3.2 Nursery techniques

The success of seedling production in the nursery not only depends on efficient management or resources but also availability of the resources in the right quality and quantity. The location of a tree nursery is influenced by

(1) Accessibility
(2) Good drainage
(3) Source of good fertile soil
(4) Reliable source of water
(5) Security

3.3 Nursery design and layout

A nursery should have an office, storage for keeping the nursery tools safely and in good condition, working shed, seed germination bed, soil, manure and sand storage area, soil mixing area, seedling beds, toilets, water system, store/office all strategically located within the nursery and fence around the nursery to keep livestock and intruders away.

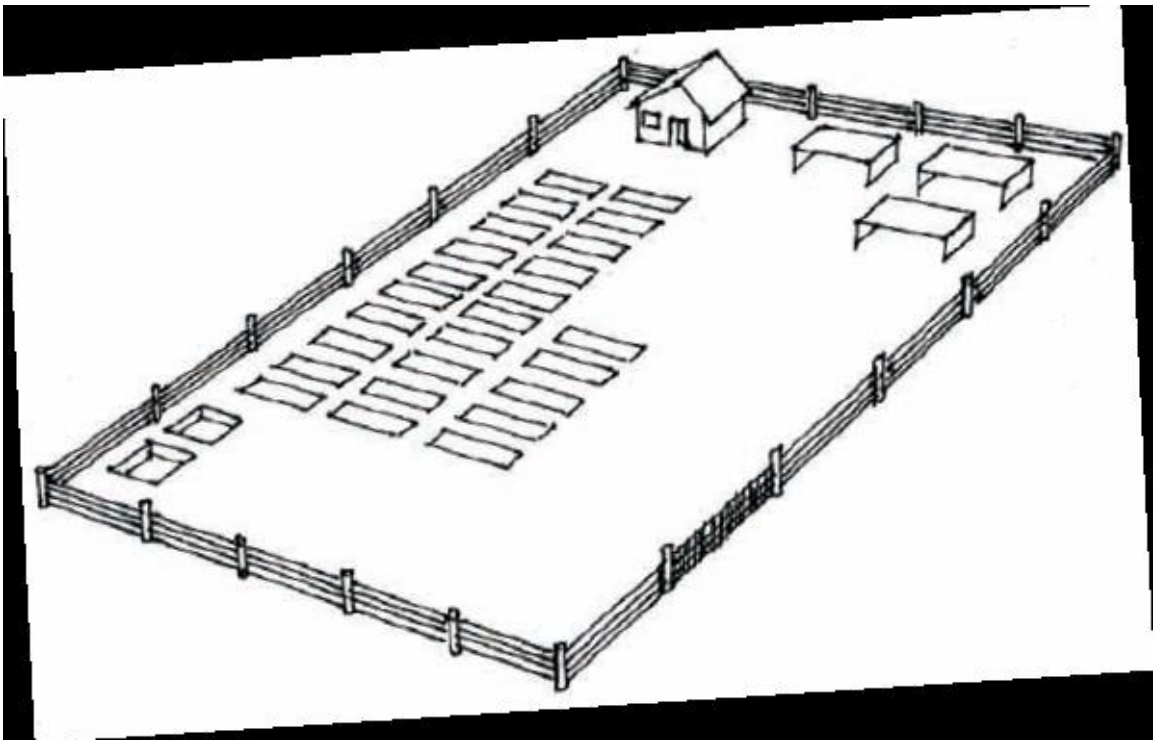

Figure 1: Nursery layout

Nursery beds

Nursery beds should be constructed at least 18 cm high from the ground and one metre wide.

This is to allow workability inside the beds

Are the beds of desired width (1 metre wide)?

Are the beds oriented in east to west direction?

Are there sufficient paths between the beds (0.8-1 metre)

Are the seedling beds labeled as per species grown?

Plate 1: Seedling beds

Seed beds

Seed sowing beds should have good drainage and be preferably constructed using gravel, broken stones and river sand. If permanent seedbeds are constructed they should also be 1 metre wide and of any length.

Plate 2: Temporary seedbed

Plate 3: Permanent seed bed

3.4 Soil media

Standard seed-bed soil mixtures consist of sieved black forest or top soil, and sieved sand at a ratio of 1:1. This ratio can vary depending on whether the clay or sand component is higher in the soil build up. The forest soil improves the soil moisture holding capacity for better germination, while the sand improves soil texture for better root penetration and ease of lifting during pricking out.

As much as possible, the seedling growing in the nursery should meet the soil condition they will experience in the field. The soil should be collected from a forest areas. The soil must have good physical structure and humus content. The surface layer consisting of grass, sticks, roots is removed to a depth of 10cm; the depth at which soil is collected. It is important that the soil is collected 2-3 months prior to potting so that the organic matter can decay and the seeds of weeds germinate can be removed easily, and soil must be sieved before mixing to remove stones, branches, roots and other unnecessary matters. However, roots and other unnecessary matters. However if it is late, sieving should be recommended immediately after collection of soil. The soil is mixed with cow manure in the ratio of four parts of soil to one part of manure.

3.5 Substrates

Most nurseries use mixtures of topsoil with organic and inorganic additions. However, these don't always allow the development of a good fibrous root system. In this section, we discuss what makes a good substrate and describe a variety of organic and mineral substrates suitable for small scale tree nurseries in the tropics.

Good plant development depends to a large part on the growing medium used. If a plant develops a good root system in a well-balanced substrate, this does not mean that the plant is pampered and will not adapt to the harsh life outside a nursery. In fact, the opposite applies. To survive in the harsh environment of a field, often without additional watering and fertilizing, a plant needs a well-developed and strong root system. The development of a healthy root system depends not only on the genetic properties of the plant but to a large extent on the physical and chemical properties of the substrate used.

3.5.1 Physical and chemical properties of a good substrate

A substrate should:

- be light in weight to ease transport to the planting site
- hold cuttings or seedlings firmly in place
- retain enough moisture to avoid need for frequent watering
- be porous enough for excess water to drain easily
- allow sufficient aeration of the roots
- be free from seeds, nematodes and diseases
- be able to be sterilized without changing its properties
- have enough nutrients for a healthy initial development of plants
- not have a high salinity level
- have a suitable pH
- be stable and not swell or shrink excessively or crust over in the sun.

The substrate properties that influence seedling growth can be divided into physical properties (water-holding capacity, porosity, plasticity and bulk density) and chemical properties (fertility, acidity and buffer capacity).

Table 1: Physical and chemical properties of soil

Physical properties	
Water-holding capacity	A substrate that allows a large amount of water to be held without waterlogging does not need frequent irrigation. The water-holding capacity is also a function of the container used. In shallow containers the substrate has a higher water-holding capacity than in deep containers
Porosity	A good porosity is needed to allow sufficient oxygen to reach the roots to prevent rotting. All living cells, including plant roots, need oxygen for respiration and growth, and they give off carbon dioxide. To maintain adequate oxygen and carbon dioxide levels in the substrate, gas exchange with the atmosphere must be guaranteed. An oxygen content of below 12% in the substrate inhibits new root initiation; between 5 and 10% the levels are too low for established roots to grow; and at levels below 3%, roots do not function and eventually they die. Desirable total porosity values which maintain oxygen levels above 12% are around 50–80% by volume. Clay soils, which are unsuitable for seedling production, can have values of 40% or lower.
Plasticity	A substrate that shrinks and cracks when drying, such as a clayey soil, damages the plants by shearing off roots.
Bulk density (weight per volume)	A substrate that has a light weight is easier to transport to the field. However, containers have to be sufficiently heavy so that they do not get blown over in the wind.
Chemical properties	
Fertility	As soon as a seedling has used up the nutrients provided by its cotyledons (about two weeks after germination), it needs nutrients from the growth medium. The basic nutrients, of which plants require relatively large amounts, are nitrogen (N), phosphorus (P) and potassium (K). Plants also need very small amounts of other nutrients (‘micronutrients’) and deficiencies in micronutrients can occur in the nursery. The micronutrients that agroforestry trees are most often lacking are iron (yellow, ‘chlorotic’ leaves), especially in soils with a high pH or those derived from limestone, and

	boron (shoot tip dries out), especially in soils from igneous rocks.
Acidity	The right substrate pH is very important for healthy plant development. The reason for this is that nutrients become available for plants at different pH levels. The optimum is around 5.5 for organic soils and around 6.5 for mineral soils. Most plants grow best in a medium with near-neutral pH (5.5–6.5), although some plants are particularly tolerant of acidity (for example *Inga edulis, Casuarina junghuhniana*) or alkalinity (for example Prosopis chilensis, Tecoma stans).
Cation exchange capacity	The cation exchange capacity (CEC) is the ability of a material to adsorb positively charged ions ('cations'). It is one of the most important factors affecting the fertility of a growth substrate. The main cations involved in plant nutrition are calcium, magnesium, potassium and ammonium, listed in order of decreasing retention in the substrate. Many micronutrients are also adsorbed, such as iron, manganese, zinc and copper. These nutrients are stored on growth medium particles until they are taken up by the root system. In practical terms, the CEC indicates the fertilizer storage capacity of the substrate and indicates how frequently fertilizer needs to be applied. Some soils contain high amounts of clays which absorb cations so strongly that they become unavailable for plant nutrition (mineral 'fixation'). These soils are unsuitable for nursery purposes. Although the CEC of some soil-less substrates is very high, anions get washed out easily and need to be replenished frequently. This is particularly important for phosphorus and for nitrogen in the form of nitrate. Mixing a slow-release fertilizer, such as rock phosphate, into the substrate before planting can help alleviate this problem.

Table 2: Elements and their roles

Nutrient	**Role**	**Symptoms**
Nitrogen (N)	Important component of amino	Old leaves turn yellow,

	acids and proteins.	plant growth retarded, small leaves. Be careful: too much nitrogen leads to overgrown plants which are highly susceptible to diseases.
Phosphorus (P)	Provides energy (ATP). Helps in transport of assimilates during photosynthesis. Important functions in fruit ripening.	Small plants with erect growth habit; thin stems, slow growth. Leaves appear dirty grey-green, sometimes red.
Potassium (K)	Important in maintaining cell turgor, phloem transport, cell growth and cell wall development (K deficiency leads to susceptibility to pests because cell walls are weakened).	Older leaves show first chlorotic, later necrotic borders. Younger leaves remain small.
Calcium (Ca)	Stabilizes cell membranes and cell walls, interacts with plant hormones. Ca is extremely immobile and can only be taken up through young, unlignified roots.	Deficiency is often only visible in retarded growth.
Magnesium (Mg)	Component of chlorophyll– photosynthesis is hindered when deficient. Binds ATP to enzymes. Important for protein synthesis.	Old leaves chlorotic from middle or between veins, rarely necrotic. Leaves orange-yellow, drop prematurely.
Sulphur (S)	Component of etheric oils, vitamin B, vitamin H, amino acids, and has important functions in protein synthesis.	Similar to N-deficiency but symptoms show first on young leaves.
Iron (Fe)	Component of chloroplasts. Part of the redox system in the electron transport during assimilation, and important for RNA synthesis.	Young leaves turn yellow to white.
Manganese (Mn)	Important for enzyme activation, photolysis. When deficient, protein synthesis and carbohydrate formation are hindered.	Youngest leaves show chlorotic spots, later they grow into necrotic areas parallel to the veins.
Copper (Cu)	Found in chloroplasts. Important for carbohydrate synthesis and protein synthesis.	Youngest leaves are chlorotic or necrotic, fruit set is insufficient.

Zinc (Zn)	Has enzyme activating function, e.g. starch synthetase; is found in chloroplasts.	Small leaves and short internodes; thin shoots.
Molybdenum (Mo)	Important component of enzymes, specifically nitrate reductase and nitrogenase. Essential element for all nitrogen-fixing plants.	Old leaves develop necrotic borders, often the symptoms are caused by secondary N-deficiency.
Boron (B)	Found in cell walls, important for transport of assimilates and cell growth. If deficient, shoot tip dries.	Youngest leaves are deformed, thick, dark green to greyish. Root system development is hindered.
Chlorine (Cl)	Important in maintaining cell tugor, increases sugar content in fruits.	Deficiency symptoms occur only in halophytes (salt-loving plants), mainly as loss in turgor.

3.6 Root system development

As soon as a seedling is established, either a few days after germination or after pricking out, both roots and shoots begin growing rapidly. This phase is as important as the establishment phase. Root development is important for good inoculation with symbionts, for efficient nutrient uptake and for out planting success. The number of fine roots with growing points largely determines the ability of the seedling to recover and start growing after planting out. If the root system is small and/or distorted, the tree cannot anchor itself sufficiently in the ground and is prone to wind-throw or lodging when waterlogged.

The appearance of a healthy root system is of course different for species with a strong tap root, than it is for those with a mass of shallow roots. However, most tree seedlings have a straight, slightly tapering main root and a large mass of fibrous roots. Healthy roots are not bent, crossing or injured. Knotted and bent roots are common in plants that have been left in the nursery too long or have been pricked out without the necessary care. These plants cannot survive in the field because the crossing roots may eventually strangle the tree or they may die back and become vulnerable to disease and termite attacks. It is worth sacrificing a few plants every now and then to have a look at what usually remains unseen: the roots of the seedlings (see figure below). Compare with the healthy root system of the seedling on the right. You can carry this through to field plantings — dig up and inspect trees after months or years to see how the root system has

developed. This is especially important when a planting has failed. When the plants are uprooted, take the time to examine the root systems. You might be surprised how often unsuccessful tree development can be attributed to root deformities.

Figure 2: Examples of bent and looped seedling root systems.
Compare with the healthy root system of the seedling on the right.

3.7 Timing and Seed sowing schedules

The time for sowing a specific type of seed depends mainly on the time it takes to attain plantable size. In this case, the plantable size stock is 30 to 50 centimeters. The main reason for this is for the seedlings to develop a proportionate root system. Very small seedlings have been found to wither and die because of poorly developed root systems. This is particularly so if the rains fade of immediately after planting. Overgrown seedlings at the nursery level tend to die because the root systems are not able to support the large shoots in terms of nutrients and moisture requirements. It is therefore important that a seed sowing programme that takes into account the growth rate of specific species is developed and properly followed. From

KEFRI/JICA research partnership, schedules for various dry land species have been developed as shown in the table below (Table 4):

Table 3: Sample Nursery Calendar

Activities	Months of the year											
	J	F	M	A	M	J	J	A	S	O	N	D
Procure seeds												
Source for soil/mixing												
Sowing												
Seedling production												
Weeding												
Inventory and sales												
Planting out												
Annual production tally												

Table 4: Sowing schedule of different tree species in the ASALs of Eastern Kenya

No.	Species	Month						
		2	3	4	5	6	7	8
1.	*Acacia abyssinica*							
2.	*Acacia gerradii*							
3.	*Acacia nilotica*							
4.	*Acacia polyacantha*							
5.	*Albizia amara*							
6.	*Albizia anthelmintica*							

7.	*Azadarachta indica*							
8.	*Senna siamea*							
9.	*Senna spectabilis*							
10.	*Croton Megalocarpus*							
11.	*Dalbergia melanoxylon*							
12	*Eucalyptus camaldulensis*							
13	*Gmelina arborea*							
14.	*Grevillea robusta*							
15.	*Melia volkensii*							
16.	*Parkinisonia aculeata*							
17.	*Prosopis juliflora*							
18.	*Tamarindus indica*							
19.	*Terminalia brownii*							
20.	*Terminalia mentalis*							
21.	*Osyris lanceolata*							
22.	*Terminalia prunoiodes*							
23.	*Moringa oleifera*							
24.	*Delonix regia*							

3.8 Pricking out

Seeds sow in boxes and seed beds once germinated have to be transferred into pots a process known as pricking out. Seedlings should be pricked out at the cotyledon or first leaf stage. When pricking out, the tender seedlings should be held with a lot of care preferably by the leaves not the collar or stem. Before seedlings are pricked out they must be well watered. This also applies to after pricking out is done under shade. Only healthy seedlings which have been uprooted from the seed-bed awaiting pricking into the pots should be kept in a tin or any other maturation container.

Plate 4: Pricking out

What to observe

- Injuries at the neck of the seedlings due to pressure at pricking out
- Transplanting damaged seedlings
- Size of seedling at pricking out (cotyledon or first leaf stage)
- Large plants with long roots
- Seedlings that appear sick or deformed
- One seedling centrally place in every tube
- Young and tender seedlings kept under shade after pricking out
- Pricking out plants into dry soil and then watering them
- Constructing shades after pricking out is done
- Pricking out in direct, hot sunlight

- ❖ Transplanting damaged seedlings
- ❖ Carrying seedlings in tie hand or on a plate without water
- ❖ Preparing the holes with a finger
- ❖ Roots bending upwards

4.0 SEEDLING CARE AND MAINTENANCE

4.1 Shading

It is necessary to control or minimize evaporation by protecting the nursery bed from direct sun. After pricking out the seedlings should be kept in full shade for 2-3 weeks. The shading material used may be grass net made locally. Some of the species that require shade are *Cassia siamea, Casuarina equisetifolia* while *Acacia polyacantha Tamarindus indica, Prosopis juliflora* and *Croton megalocarpus* may not require shade.

What to observe

- Are the recently pricked out seedlings well shaded? Check the status of the recently pricked out seedlings
- Are the germinating seedlings shaded?
- Are there wilting pricked out seedlings and seedlings on seed beds?

4.2 Watering

The seedlings should be watered twice each day, early in the morning and late in the afternoon when sunshine is not too strong. 30L/1,000 seedlings is used. They should never be watered at mid-day. In the rainy season watering should be done once a day or none at all but the nursery headman should watch whether the stock is not under stress. During watering the intention is to keep the soul highly moist but never sodden or dry. Note, however that both over-watering and under-watering are bad for the seedlings. Over-watering may lead to root rot as a result of water logging and may also encourage proliferation of damping off fungi, while under-watering will result in poor root development since the water will moisten only the surface layer of the soil.

The nursery beds/pots should not be watered using a hosepipe because strong jets of water are likely to wash away the soil and/or damage the seedlings. The water should be evenly distributed over the nursery using a watering can or an old tin with holes drilled at the bottom.

Alternatively, a leafy branch can be used. Dip the branch into water and sprinkle the water onto the bed or pour the water down the branch onto the soil.***

What to observe

Proper watering should be evidenced by:

- Moist pots
- Absence of signs of seedlings wilting
- Absence of algae in the pots
- Absence of hard crust at the tops
- Damping off fungi

*A few seedlings can be sampled and the slightly pressing them to determine if they are soft indicating adequate watering

4.3 Weeding

Weeds are a threat to healthy development of seedlings and must therefore be controlled. This is because they compete with seedlings for water, nutrients and light. Rouging i.e. the gentle pulling out of the unwanted growth is usually an appropriate method of weed control. Secondary weeding is done not only to control weeds but also in improving the aeration and water percolation. Roots can penetrate easily into the soil which facilitates uptake of nutrients. Experience has shown that repeated watering of the seedlings leads to compaction of the soil in the pot thereby deteriorating the physical properties of the soil. This therefore makes cultivation an indispensable exercise. Convenient tools for the operation are spatulas, dibblers etc***

Cleaning around the beds

Weeds emerge not only in the pots, but also around the beds. These weeds attract crickets, caterpillars and other insects, which feed on seedlings and also give then a place to hide. Remove all the weeds around the beds with jembes and do not leave any rubbish around.

Plate 5: Weeding

Check on:

- Presence of weeds both inside the pot and between the beds
- Proper disposal of polythene tubes

4.4 Root pruning

When seedlings have reached a certain size, their roots become longer than the length of the pots. If the roots are left without pruning, they penetrate into the ground and develop a root system. It is important that strong roots are not allowed to develop because once they are cut the seedlings are likely to be weakened. Hence periodical root pruning is required before the root system is formed in the ground. This is done after every 2-3 weeks it is advisable that the nursery stock is watered before and after root pruning. The watering after pruning helps the plant withstand moisture stress. When the seedlings are well root pruned injury to the roots during

sorting and grading, removal of seedlings form the bed during sale is minimized. In addition, a well root pruned seedlings will develop good fibrous roots for better establishment when planted out in the field.

Plate 6: Root pruning

What to observe

Roots that have grown deep into the ground (sample a few plants by lifting them up)

4.4 Hardening up

If seedlings are over-watered and partially shaded up to the time they are out planted to the field, the resulting survival will be low. This is because the act of planting is a shock to the seedlings especially when out planting. Seedlings in the nursery are usually weak and succulent. They wilt and die in a short time when exposed to the intense sunlight. Seedlings should therefore be prepared gradually for the field conditions. One month before the end of the season, watering frequency is reduced to once a day its intensity is reduced from 30 litres to 20 litres/1000 seedlings. Stock is however not allowed to seriously wither but it is the intention to stop soft and

succulent growth. The seedlings are separated and rearranged in rows of threes so that they get fully exposed to sunlight.

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What to observe

Succulent seedlings a few days to plant out

Signs of overgrown plants are

• Lack of leaves, as old leaves fall and young ones are not produced

• A root system that lacks young, fibrous roots

• The tap root is often grown into the ground

• Root deformities, for example roots coiling at the bottom

of the bag

• Lignification of the whole stem

• Very short tip internodes but in general a tall, thin stem

5.0 SEEDLING QUALITY

This chapter describes what we mean by 'quality' seedlings. Here, we discuss targeting seedlings to the conditions you expect at the site where you will plant them. We give ways to monitor plant development and describe simple routines that help to handle planting stock or to reduce variation amongst seedlings.

Seedling quality is a concept, widely used in forestry, which has received considerable attention in developed countries. It is important because afforestation seedlings cannot receive the same care that may be given to individual ornamental or fruit trees. After they are planted, the seedlings have to survive without irrigation or fertilizer, and this is often the case in tropical smallholder agroforestry sites too. Many studies have shown that field survival and productivity are related to the quality of the seedlings used.

Seedling quality depends on:

- the ability to produce new roots quickly
- the speed with which seedlings get anchored in the ground,
- and start assimilating and growing after planting out
- a well-developed root system
- sun-adapted foliage

- a large root collar diameter
- a balanced shoot: root ratio
- good carbohydrate reserves
- an optimum mineral nutrition content
- the establishment of adequate mycorrhizal
- or *Rhizobium* infection

Many seedling quality characteristics, such as the shoot: root ratio, are difficult to observe and/or require destructive sampling. The shoot: root ratio is an important measure for seedling survival. It relates the transpiring area (shoot) to the water absorbing area (roots). It is usually measured by determining root and shoot dry weights. A good ratio one which indicates a healthy plant- is 1:1 to 1:2 shoot: root mass. A less rigorous, but non-destructive, index is the 'sturdiness quotient', which compares height (in cm) over root collar diameter (in mm). A small quotient indicates a sturdy plant with a higher expected chance of survival, especially on windy or dry sites. A sturdiness quotient higher than 6 is undesirable. Nursery bed density, shading, pricking out techniques, seedling size at planting, watering and fertilizing before and after planting out all these have significant and long-lasting effects on seedling quality and subsequent tree development, insect and pest resistance, and tolerance to environmental stresses such as drought.

6.0 TREE SEED

6.1 Introduction

A sustainable supply of high quality tree germplasm (seeds, cuttings or other propagules) is fundamental to the success of afforestation programmes, agroforestry scaling-up initiatives and tree planting in general. Lack of high quality tree planting material has frequently been identified as a major constraint to the successful establishment of forest plantation and agroforestry production systems. It is true to say that high quality seed does not cost, rather it pays.

Tree growing compared to growing of agricultural crops in general takes longer for one to sell the produce. Inherently then, it is quite heart breaking to make mistakes in tree growing as in most cases, the errors are not easy to correct. One of the most insidious mistakes that are made in tree planting endeavours is to ignore the role of quality seed. Unfortunately, mistakes of using

poor quality tree seed when they manifest themselves leave the tree grower in a quandary. Unlike in crop-based agriculture where a mistake in using of poor quality seed in maize can be corrected the following season, tree growing by its nature might leave the tree grower stuck with a poor tree crop till the rotation period which could be up to 25 years. The economic loss in terms of foregone earnings could run to millions of shillings depending on the plantation size. The converse is true – one will make millions of shillings by use of high quality tree seeds.

6.2 What is a seed?

Seed is the reproductive material of flowering plants. In biological sense, seed is the product of fertilization between the male and female gametes. True seeds are only found in higher plants where all trees belong. However seed can in the day to day language refer to cuttings or any vegetative material that is used to regenerate plants.

Seed quality/genetic quality

Seed quality is comprised of three components.

- ✓ Physical quality: Quality related to physical characteristics, such as size, color, age, seed coat condition, occurrence of cracks, pest and disease attacks, or other damage.
- ✓ Physiological quality: Quality related to physiological characteristics, such as maturity, moisture content, or germination ability.
- ✓ Genetic quality: Quality related to characteristics inherited from the parent trees.

The seed collector plays a big role in determining the quality of seed (see section on seed collection)

Seed quality helps determine:

- The quantity of seed that should be sown to produce the required number of seedlings. For the same tree species, less quantity of seeds will be needed when the seeds are of high purity and of high germination.
- The number, health and vigor of the resulting seedlings; and

• The characteristics of the resulting seedlings and mature trees, such as growth rate, biomass production (wood, leaves, etc), fruit and seed production, stem form (straightness, diameter, branchiness, merchantable length), general health and susceptibility to pests and diseases.

6.3 What is a seed source and provenance?

A seed source is individual trees or stands, natural or planted, from which seed is collected. A seed source is described by the tree species collected, the administrative location, and the map attributes of latitude, longitude and altitude. A key attribute that also is used to describe the seed source is the nature of how the seed source was developed. This key attribute describes different types of seed sources as described in section 3.4. Once seed is collected, the geographical location of the seed source is commonly equated to the provenance of the seed. However, the strict use of the name, provenance is the origin of the propagative materials that was used in establishing the seed source. In natural stands used as seed source, the provenance and seed source are the same.

6.4 Types of seed sources and their characteristics

Seed sources can be categorized into: general seed source; selected single trees; selected seed stands; established seed stands and seed orchards. General see sources are naturally occurring planted trees with superior traits as dictated by end use. Selected single trees are specific outstanding individuals that are used as a seed source. Selected seed stands are planted stands whose original planting is not for seed collection but are later picked for seed production due to their outstanding performance. Established seed stands and seed orchards are purposely planted and managed for seed production. Seed orchards should be planted by breeders as they require specified configurations.

6.5 Seed collection and handling

Seed collection and handling comprises of the following activities: Flower survey; seed survey, planning for collection, seed collection, and seed processing. Table 5 highlights the key elements of each activity

Table 5: Seed collection and handling programme

Activity	Key elements
Flower survey	Determine occurrence, abundance and extent of flowering to make informed decision on: • anticipated size of seed crop • expected seed quality which is correlated to high abundance and extensive flowering
Seed survey	Make informed decision on: • anticipated size of seed crop and human and physical resources to deploy • maturation and timing of collection • expected seed quality based on extent of any attack by pests and diseases Maturation and insect / disease damage should be assessed through a cutting test where the samples of fruits should be cut open
Planning seed collection	Based on quantity to collect, arrange for: • mobilization of required physical and human resources such as cotton bags for collecting seeds, sisal sacks for transportation, canvas for capturing seeds during collection, climbing equipment and first aid kit • permits • funds
Seed collection	Observe the rules for collection as follows: • collect only from healthy trees • collect from only well performing trees with desired traits • collect from across the seed source • maintain a distance of at least 50 m from one tree to the other in general, selected single trees • Collect from at least 30 mother trees • Collect roughly equal amount of fruits from any given tree • Conduct cutting test to determine maturity and health integrity • Avoid collection of fallen fruits unless induced to fall during collection • Document seed collected
Seed processing	Seed processing include extraction, cleaning and drying Extraction of seed depends on nature of fruits • Extract seed from pulpy fruits as soon as possible by squeezing and rubbing it off if soft pulp or by pounding in mortar and pestle for hard pulp or soft

	pulp with hard seeds • For dry dehiscent fruits drying in the sun following by gentle threshing is an effective extraction process • Drying and tumbling assist in extraction of seeds borne in cones • collect from across the seed source • maintain a distance of at least 50 m from one tree to the other in general, selected single trees Depending on the species, extracted seed require cleaning to improve purity through • hand sorting • Winnowing • Sieving • floatation • mechanical blowers • Dewinging Most seed will withstand drying. For this species, the more seed is dried, the longer it lasts in storage. • dry seed in well ventilated seed beds under direct sunlight • Spread seed in thin layers to ensure rapid drying and avoid overheating Some seeds like for *Prunus africana*, *Syzygium spp*, *Azadirachta indica, Aningeria adolfi-friederici, Podocarpus latifolius, Trichilia emetica* and *Warburgia ugandensis* do not withstand drying and should be sown as soon as possibke after processing.

6.6 Seed storage

Seed is stored to ensure the supply of seed for planting whenever it is need or to ensure sowing is synchronized with conducive weather patterns for tree growing. Only seed that tolerate drying (orthodox seed) should be stored as seed is only stored after drying. Seed that does not tolerate drying (recalcitrant seed) should be sown as soon as possible after processing but the short term storage of not more than a month can be done by mixing the seed with moist saw dust and storing in open containers under shade.

For orthodox seeds;

- Store seed in airtight containers

- Store seed in low temperatures preferably in fridges
- Seed stored in room storage if properly dried can last several years.

6.7 Pre sowing treatments/instructions

Pretreatment is the measure taken to make viable but dormant seeds germinate easily. Not all seeds requirement pretreatment. But seeds with hard seed coats generally require some form of pre-sowing treatments to hasten and promote uniform germination. Common pretreatments for tree seed include soaking seed in cold water, soaking in hot water, and nipping. Table 6 present pre-treatment for various tree seed.

Table 6. Pretreatment, expected seedlings per a kilo of seed and seed storage behavior of seed for selected tree species

	Species	**Pre-treatment**	**Expected seedlings/kg of seed**	**Storage behaviour**
1	*Acacia mearnisii*	Soak in boiled water and leave to cool overnight	34,438	Orthodox
2	*Acacia melanoxylon*	Pour boiling water over seed and allow to cool 24 hours	35,035	Orthodox
3	*Acacia polyacantha*	Nick seed coat by scalpel, knife, file or nail clipper	11,025	Orthodox
4	*Acacia xanthophloea*	Nick seed coat by scalpel, knife, file or nail clipper	14,553	Orthodox
5	*Acrocarpus fraxinifolius*	Nick seed coat by scalpel, knife, file or nail clipper	14,823	Orthodox
6	*Albizia gummifera*	Nick seed coat by scalpel, knife, file or nail clipper	5,096	Orthodox
7	*Brachylaena huillensis*	No pre-treatment required	144,500	Orthodox
8	*Calliandra calothyrsus*	Nick seed coat by scalpel, knife, file or nail clipper	11,466	Orthodox
9	*Callitris robusta*	No pre-treatment required	29,400	Orthodox
10	*Casuarina jughuniana*	No pre-treatment required	581,875	Orthodox
11	*Cordian africana*	Soak in cold water overnight	3,504	Orthodox
12	*Croton macrostachyus*	No pre-treatment required	8,624	Orthodox
13	*Croton megalocarpus*	No pre-treatment required	1,083	Orthodox
14	*Cupressus lusitanica*	No pre-treatment required	50,625	Orthodox

	Species	Pre-treatment	Expected seedlings/kg of seed	Storage behaviour
15	*Dombeya goetzenii*	No pre-treatment required	20,758	Orthodox
16	*Dovyalis caffra*	No pre-treatment required	17,850	Orthodox
17	*Eucalyptus grandis*	No pre-treatment required	300,000	Orthodox
18	*Faidherbia albida*	Nick seed coat by scalpel, knife, file or nail clipper	5,182	Orthodox
19	*Grevellia robusta*	No pre-treatment required	41,905	Orthodox
20	*Jacaranda mimosifolia*	No pre-treatment required	45,045	Orthodox
21	*Juniperus procera*	Pour hot water (70^0C) over seed and allow to cool 24 hours	15,960	Orthodox
22	*Leucaena diversifolia*	Pour hot water (90^0C) over seed and allow to cool 24 hours	16,758	Orthodox
23	*Maesopsis eminii*	Crack pericap by stone, hammer or vice	277	Orthodox
24	*Markhamia lutea*	No pre-treatment required	39,150	Orthodox
25	*Melia azedarach*	No pre-treatment required	204	Orthodox
26	*Melia volkensii*	Break caruncle off the seed and soak in cold water overnight, cut longitudinally through the perisperm and endosperm	1,361	Orthodox
27	*Moringa oleifera*	No pre-treatment required	3,325	Orthodox
28	*Newtonia buchananii*	No pre-treatment required	1,568	Orthodox
29	*Newtonia hilderbrandtii*	No pre-treatment required	1,995	Orthodox
30	*Olea capensis*	Crack pericap by stone, hammer or vice	1,029	Orthodox
31	*Pinus patula*	No pre-treatment required	92,625	Orthodox
32	*Podocarpus falcatus*	Crack pericap by stone, hammer or vice	386	Orthodox
33	*Podocarpus latifolia*	No pre-treatment required	1,117	Recalcitrant
34	*Prunus africana*	No pre-treatment required	2,280	Recalcitrant
35	*Schinus molle*	Pour cold water over seeds	11,662	Orthodox
36	*Senna siamea*	Pour boiling water over seed and allow to coll 24 hours	18,525	Orthodox
37	*Sesbania sesban*	Pour hot water (90^0C) over seed and allow to coll 24 hours	62,700	Orthodox
38	*Spathodea campanulata*	No pre-treatment required	55,688	Orthodox
39	*Syzygium guineense*	No pre-treatment required	1,259	Recalcitrant

	Species	Pre-treatment	Expected seedlings/kg of seed	Storage behaviour
40	*Terminalia brownii*	V-shaped nipping	735	Orthodox
41	*Terminalia mentalis*	V-shaped nipping	1,176	Orthodox
42	*Thevetia peruviana*	No pre-treatment required	238	Intermediate
43	*Trichilia emetica*	No pre-treatment required	532	Recalcitrant
44	*Vitex keniensis*	Remove aril by maceration in water	941	Orthodox
45	*Warbugia ugandensis*	No pre-treatment required	6,650	Recalcitrant

6.8 Seed documentation/record

Seed documentation serves to give seed a unique reference number that allows suppliers and users keep track of the performance of a particular seed lot. Documentation also facilitates seed exchange and trade. The supplier is able to serve the user better by matching the request for seed to a particular seed lot whose documentation details disclose that the seed lot is best fitted to the users' requirement.

Seed documentation is done through the whole seed production system that includes both technical and managerial aspects

Technical Documentation include;

- Seed stand establishment (identification) and development
- Seed sources details
- Phenology data (seed survey)
- Seed collection and handling
- Seed quality test results
- Seed storage and
- Seed distribution/marketing

The other type of seed documentation is **Managerial documentation** that is used to aid in the management of a seed production unit and include cost of operations

Important details captured in documentation for each stage in the seed production cycle are shown in Table 7.

Table 7: Details to capture in seed documentation

Stage in Seed Production Cycle	Details to capture
Seed stand establishment and development	Species, origin/provenance of basic material, identity of genotypes, silvicultural tending, phenology, area, maps, edaphic, geographic, ecological and climatic conditions, mapping of the stand, sketch map of its location
Seed source	Species, origin/provenance of basic material, category of seed source, locality (sketch map), ecological and climatic conditions, ownership, area, edaphic factors, topography, accessibility, year of planting
Phenology	Species, locality, area, date of recording, flowering integrity, fruiting stage and expected date of maturity
Seed collection and handling	Date of collection, collector, species, seed source, cutting test, method of collection, transportation containers, duration of temporary storage, extraction method and drying method
Seed test results	Species, cutting test ,purity, moisture content, seed weight, health (insects pests and pathogens) other tests eg tetrazolium test)
Seed lot	Seed source details (as presented), collection and handling, seed test results, identity or batch number
Seed storage	Species, seed lot identity/batch number, weight stored, running balance
Seed dispatch	Species, seed lot identity/batch number, customer, weight required, weight issued, date dispatched, seed advice note

The details to capture in the seed production cycle shows a lot of details are repeated from one stage to another. To avoid confusion a seed collection form can be used that incorporates a lot of data under one cover. The form should capture details on seed source, seed collection and handling and seed testing results. A seed collection label which accompanies seed lot in all its stages from collection to storage has a code which when necessary is used to profile more details on a seed lot source, collection and handling, test results, storage and dispatch.

7.0 PLANT PATHOLOGY

7.1 Introduction

Major diseases affecting trees may be caused by fungi, bacteria and viruses. Many plant pathogens can be found in soil. Fungi such as Cylindrocladium, Pythium, Phytophthora, Fusarium and Rhizoctonia are common. Fungi cause the most damage because they spread by tiny spores and can multiply very quickly. However, little attention has been paid to disease problems associated with these trees. These are gradually gaining recognition due to their occurrence and effect. In nurseries, heavy losses can occur when attacked seedlings die. The identification of tree diseases is of paramount importance if appropriate management is to be undertaken. The major diseases occurring in nurseries are: Damping off, leaf spot, wilts, powdery mildews, blights, cankers and root rots. The control of these diseases is an important aspect in the management so as to realize the full benefit of tree farming. The knowledge of the various types of diseases helps to determine the method of control to be applied. For those that are known to occur, there are various methods or options that can be used to manage them. Integrated pest management (IPM) is considered as a better approach to the control of diseases. IPM does not promote any one control method above another, or to the exclusion of all other methods. IPM advocates the employment of those control methods which are most effective, efficient and economical. These methods involve prevention, cultural, mechanical and use of fungicides.

7.2 What is a tree disease?

- Any deviation in the normal functioning of a plant caused by some type of agent.
- Any malfunctioning of host cells and tissues that result from attack by a pathogenic agent or environmental factor and leads to development of symptoms.

7.3 Disease triangle

The disease triangle is a conceptual model for disease. It emphasizes that disease is not just caused by a pathogen, but by the interaction of the environment, a pathogen, and a host to produce disease. It also emphasizes that disease and pathogen are not the same thing.

Figure 3: Disease triangle

Signs and symptoms

Signs are physical appearances of a pathogen, either somatic tissues or fruiting. Anything you see that is primarily made of pathogen tissue can be called a sign. Symptoms are alterations in the appearance of the host due to disease.

7.4 Types of diseases and their control

7.4.1 Damping off (Stem rot of seedlings)

Damping-off pathogens may be endemic in nursery soil without causing damage but can cause disease when environmental conditions are favorable. The main environmental factors influencing damping-off are soil pH, moisture and temperature. Excessive soil moisture and moderate temperatures favor development of some pathogens such as Pythium. The disease usually is most severe in nursery soils that are excessively wet. It occurs on young seedlings after germination. Nurseries throughout Kenya have experienced losses due to damping off. Post-emergence damping-off affects young seedlings before their stems become woody causing soft rot. These rot away at the soil level causing the seedlings to fall over and die. It is caused by fungi that are common in the soil. They include species of Pythium, Fusarium, Botrytis, Rhizoctonia and Alternaria. The fungi if present in the soil may grow rapidly when conditions are appropriate and attack the young stems of seedlings. Examples of species affected are Pines, *Leucaena leucocephala*, *Cassia siamea*, Eucalyptus sp.

Control measures

(i) Chemicals e.g Ridomil or Bavistin.

(ii) Avoid over watering of seedlings that would result to excess moisture.

(iii) Use soils with good drainage characteristics especially when establishing nurseries

(iv) Sowing density (avoid overcrowding of seedlings by sowing fewer seeds).

7.4.2 Gray mold

7.4.2.1 Introduction

Gray mold is found in both temperate and tropical regions. The fungus is primarily spread though airborne spores. The pathogen has an extremely large number of hosts. Nearly all forest tree seedlings are susceptible to some degree. The disease commonly affects young and lower shaded branches. Gray mold occurs sporadically in nurseries and greenhouses. Causal organism

Grey mold is caused by the fungus *Botrytis cinerea* which is pathogenic and saprophytic on plant tissues. During periods of high humidity, the fungus can be seen as a thin gray web of mycelium on infected plant parts. The disease is favored by cultural practices, such as high planting densities or and shading that limit air movement and raise the humidity around the seedlings. Once established on a branch, it moves downward into the stem killing the tissues it infects.

In succulent stem tissue there are black sunken cankers usually low on the stem which finally girdles the stem. The portion of the seedlings above the girdled area dies. Grey mold is often confined to pockets of seedlings but can cause heavy mortality in highly susceptible species.

	
Botrytis infection on twig of a Eucalyptus host	**Grey mycelium on host**

Plate 7: **Botrytis infection on twig of a Eucalyptus host**

Control

Modify the environment to increase aeration and decrease humidity around the seedlings. This will reduce spore germination and growth of the fungus. Other practices include reducing seedling density for adequate spacing, improving air circulation and irrigating less frequently or early in the morning. Contact fungicides are more effective since the fungus is not systemic.

7.4.3 Leaf spots

Leaf spots are so far the most common of the foliage diseases. Seedlings raised in nurseries are attacked by a leaf spot and shot-hole disease caused by *Colletotrichum gloeosporioides.* Leafspots are circular or irregular usually surrounded by a zone paler than the healthy tissue. Later the centers of the spots fall, leaving clean shot holes. When infection is severe, the pathogen causes premature leaf fall and dieback of the leader shoot. These affect both exotic and indigenous trees. Leaf spots are caused by various fungi e.g. *Septoria sp*., *Phoma sp*. and *Alternaria sp.* They may also be caused by bacteria (e.g. Pseudomonas sp.) or viruses. Leaf spots diseases can easily be spread in nurseries. . However, leaf spot diseases should be taken more seriously if they result in moderate to complete leaf loss.

Leaf spots on *Vitex keniensis*

Leaf spots on *Prunus africana*

Plate 8: Leaf spots on *Vitex keniensis*

7.4.4 Blights

Blights are characterized by rapid infection and death of whole plants or due to extensive necrosis of leaves. Leaves of some twigs suddenly wilt and turn brown or black. Blight attacks a few twigs at a time with dead foliage on different areas of the plant. They are caused by fungi or bacteria. When they occur they are likely to spread fast within a nursery, plantation or group of trees. Bright diseases are more common in nurseries than in the field. This could be due to the susceptibility of the leaves of young seedlings and the nursery conditions.

Bright attack on Podocarpus

Dying seedling

Plate 9: Bright attack on Podocarpus

Control

(i) Use of chemical sprays available in the market for various diseases on a wide range of crops or trees eg Benlate (Ridomil), Milraz, Bayleton etc.

(ii) Phytosanitary measures - removal of diseased plant material to prevent infection of healthy plants and buildup of pathogen populations.

(iii)Use of resistant varieties of tree species.

(iv) Avoid introduction of diseased material either from within or from outside.

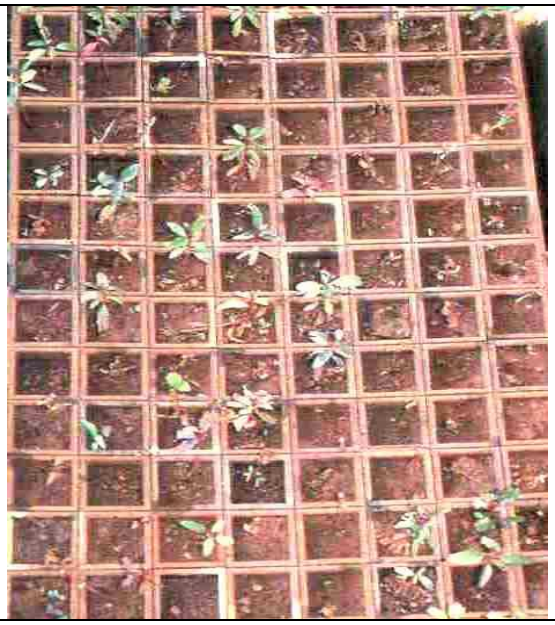
7.4.5 Wilts

Wilts result from infection of vascular system by fungi or bacteria. They affect plants by blocking the vascular system and prevent the flow of water and other materials. *F. oxysporum* attacks and kills the roots of seedlings causing chlorosis, stunting, and wilting of the top and eventually death. Examples include Fusarium wilt on *L. leucocephala*, Albizzia and Calliandra.

Control
Wilts can be controlled with systemic fungicides such as Ridomil and Bavistin.

7.4.6 Cankers
These usually affect the stems of seedlings or mature trees. These are characterized by swelling or sunken lesions and sometimes production of resin. Fungi such as Cylindrocladium, and Botryosphaeria cause them. Cylindrocladium spp. cause several kinds of damage including root rot, damping-off, needle and leaf blight, and stem cankers In Kenya cankers have been found to affect species such as Eucalyptus, Grevillea, Cypress and other species. Cankers can cause huge losses especially on nursery seedlings or cuttings.

Canker on stem of Eucalptus seedling



Seedlings losses in nursery

Plate 10: Canker on stem of Eucalyptus seedling

Control
(i) Use of a combination of chemicals eg Thiram, Benomyl

(ii) Reduction of relative humidity by avoiding overcrowding of seedlings.

(ii) Control watering to reduce moisture.

7.4.7 Powdery Mildew

Powdery mildew is one of the most widespread and easily recognized plant diseases. These occur on leaves mainly on seedlings. The leaves appear whitish due to the fungus. Affected leaves become curled and as the disease increases they turn brown and die. The disease is most commonly observed on the upper sides of the leaves. It also affects the bottom sides of leaves and young stems. Infected leaves may become distorted, turn brown and fall prematurely. Powdery mildews diseases are common on many species of plants including trees. The mildew fungi belong to the family Erysiphaceae (the true mildews). The conidial stage belongs to the form genus Acrosporium (formerly Oidium). They are parasitic on higher plants. Attack by mildews cause defoliation and reduction in growth of trees or seedlings. Plants growing in shaded areas are often the most affected.

Powdery mildew on Eucalyptus seedlings

Powdery mildew on *Prunus africana*

Plate 11: Powdery mildew on Eucalyptus seedlings

Control

The disease can be controlled by use of fungicides. Chemicals are most effective when combined with cultural controls. They can be controlled using fungicides such as Ridomil, Milraz, Kocide etc. In Kenya, severe attacks have been reported in nurseries especially on Eucalypts, *Prunus africana* and *Senna siamea*. Chemicals eg. Ridomil, Dithane and Milraz. Sanitary measures by

removal of diseased material prevents spread and buildup of pathogens. Avoid introducing diseased material in the nursery. Avoid placing seedlings in shaded areas. Use of resistant material, varieties, species or clones can also reduce disease attacks.

7.4.8 Root rots

These occur on seedlings in the nursery. In the nursery roots of seedlings may die below the soil level and eventually the whole seedling dies e.g. Fusarium root rot.

	
Root rot	**Fusarium fungus**

Plate 12: Root rot

Control

(i) Removal of dead plants including the roots after excavation or digging them up. The material should then be burnt.

(ii) Avoiding overwatering of seedlings to reduce moisture.

7.4.9 Leaf rust

Rusts can attack trees or seedlings in the nursery. It causes orange, gold, or reddish spots rupturing leaf surfaces. Rust fungus makes leaves unsightly and weakens the plant by interfering with photosynthesis. Each plant species that is susceptible to rust hosts a particular rust species that may vary from other rust species in appearance. Leaves are discolored or mottled yellow to brown. Powdery fungal clusters appear on the leaves. The powdery material can be scraped off. Leaves may become twisted and distorted and may dry and drop off. Twigs may also be infected.

	
Croton seedlings attacked by rust	**Rust fungus on leaf surface**

Plate 13: Croton seedlings attacked by rust

Control

Many rust fungi are usually harmless to the plant and rarely require control measures. Where practical, remove and destroy leaves. It can be controlled with fungicides. Affected seedlings should be removed and destroyed to prevent spread.

8.0 ENTOMOLOGY

8.1 Introduction

Tree nurseries can provide a strong foundation for production of healthy seedlings which in turn give trees the best chance to establish and maintain growth vigor upon transplanting in the field. The genetic composition of the germplasm used to propagate seedlings also comes into play in determining the growth vigor and fitness of seedlings. These considerations make it necessary to sow the best quality seed of the desired tree species in the first place. In addition, the health of tree seedlings is not only judged by absence of pests and diseases, but further encompasses providing growth media with good plant nutritional balance. Watering should also be controlled to an optimum level to prevent excessive dampness in the tree nursery. Healthy seedlings can resis attack by pests (Cram *et al*., 2012)

8.2 Tree nursery pests

Introduction to important nursery pests

Young seedlings are prone to attack by insect and other pests which can easily devour their soft, nutritious tissues. The pests that are encountered on mature trees are at times also present at the nursery stage and thus increase the tree species susceptibility to attack by particular types of pests (Nyeko and Nakabonge, 2008).

8.3 Economic importance of pests

The population buildup of organisms that are found feeding on seedlings in nurseries should be monitored and an economic threshold level determined at which it then becomes necessary to take measures to prevent it from developing into a pest situation. This is to say that action should be taken when damage to seedlings is judged to be likely to reduce the stock of available nursery stock for transplanting. As such, routine checks and monitoring for pest incidences form an important part of the nursery management procedures.

Characteristics of common nursery pests (Rebek, 2020)

8.4 Defoliators

These are organisms that feed on the foliage of seedlings. Immature and mature stages of insects and other common organisms like snails are often responsible for severe damage when they occur in pest outbreak levels. Defoliators chew the leaves and reduce their surface area, interfering with photosynsthesis and stunting growth if left unattended. Examples are the Eucalyptus snout beetle and caterpillars stages of different moths and butterflies.

Defoliating caterpillars

Plate 14: Defoliating caterpillars

8.5 Sapsuckers

Any organisms with mouthparts suitable for insertion into plant organs and by means of which they drain plant sap are regarded as suckers. They can cause economic damage when their populations build up to high levels. Examples are mites, thrips, scales, psyllids, aphids and mealy bugs.

8.6 Leaf rollers

These organisms roll up leaves to protect themselves as they chew the plant. They reduce the surface area for photosynthesis. A number of immature stages of moths and butterflies cause this problem.

8.7 Stem cutters

While feeding on plants, some organisms cut through the young stems of seedlings and cause death of affected seedlings. This is the manner in which millipedes and cutworms cause damage to nursery stock.

8.8 Gall formers

Plants react to the attack of some orgamisms by developing swellings of tissue at the points of attack which distort the growing tips of trees and can cause the loss of a leader shoot, thus deforming the plants. An example of such a pest is the Blue Gum chalcid.

Plate 15: Seedling attacked by blue gum chalcid

8.9 Root feeders

These organisms target the root system of plants which they chew or debark, leading to death of seedlings. They can be as small as termites or as large as moles (rodents). A seedling with a poor root system has little chance for establishment in the field.

8.10 Control measures

A stock of tree seedlings has great economic value as the foundation of tree planting. Since tree nurseries are confined to an area that is well demarcated, the scope of management options for pests usually includes the application of chemical pesticides. Care should be taken to select chemicals that do not cause harm to non-target organisms and which break down within short periods to avoid accumulation of chemicals in the environment. This is paricularly important as other forms of life are linked to the organisms that are present in tree nurseries. Biocides,

insecticides, rodenticides and nematocides may be applied before sowing to eliminate organisms even though there is always the chance of nurseries becoming re-colonized by pests emanating from untreated neighboring areas (Cram *et al.*, 2012)

The use of cultural control methods also compliments the integrated management of nursery pests. The common practices involve application baits to lure organisms to traps, fencing or building screens to keep out herbivorous organisms from the nursery beds, application of herbal solutions of particular local plant foliage with known pesticide qualities. Other practitioners apply ash to the soil to repel organisms from further access to seedlings in the affected sites. These methods are reported to work well and are dependent on indigenous knowledge. There is need to scientifically test the formulations and standardize them for wider application. With good management of weeds and litter, it is possible to keep nurseries clean and reduce places where organisms that attack seedlings may hide. Additionally, nursery operators with clean stock should refrain from accepting additional stock that is raised elsewhere as it can introduce pest problems in the new location (Cram et al., 2012).

9.0 TREE NURSERY RECORDS

In order to have an effective nursery management, up-to-date nursery records should be kept. The major documents include:

9.1 Workers register (Muster roll)

This is a register where attendance and daily occurrences of workers are recorded. It is maintained by the nursery supervisor. It helps in deciding the payment of workers for the days served. This is accountable document that must be handed over when the supervisors are changed.

9.2 Equipment inventory register / asset form

All nursery equipments and assets are entered into the book and their state is recorded. The book is accountable and handed over from one supervisor to another.

Equipment/material	Date of acquisition	Quantity	Cost	Condition	Remarks

9.3 Workers diary/daily assignments and observations

• Indicates daily assignments

• Achievements

• Field/Nursery observations

• Remarks

9.4 Weekly reports

A summary of tasks completed, achievements and remarks. It also summarizes all attendance and occurrences.

9.5 Seed inventory book

This is where all seeds entering the nursery are recorded. It contains all details such as:

• Introduction date

• Species name

• Batch number

• Origin/source

• Amount

• Given code number

• Date of collection

• Given germination rate

Species	**Date received**	**Quantity received**	**Date collected**	**Provenance (source)**	**Remarks**

9.6 Seedling book

• Seed code number

• Species name

• Pretreatment

• Sowing date

• Germination date

• Germination percentage

• Seedling periodic inventory (weekly/Monthly

Species name and Code	Date of sowing	Quantity sown	Total No. germinated	Total pricked out	Date of pruning	No. of seedlings		Total sales	Remarks
						Issued out	Sold		

9.7 Nursery delivery register

The record shows how seedlings have been distributed.

• Names

• Addresses

• Telephone numbers

• Email

• Number planted locally

7.8 Invoice

This is a documentation that accompanies goods (seeds/seedlings) to a buyer giving details and pricing. It is required for processing of payment for goods. It is accompanied with delivery note.

9.9 Delivery note

This is a documentation that is released with goods delivered to a user showing details of what is delivered. It must be counter signed by the receiving agent showing that goods were in good condition. It opens way for arrangements for payments.

9.10 Cash sale receipts

This is a documentation confirming that money has been received. It is usually exchanged with cash.

9.11 Visitors' book

This is a book where all visitors to the nursery are recorded including buyers. It shows the date of the visit, contact details and remarks that can help in management.

10.0 REFERENCES

Cram, M. M.; Frank, M. S. and Mallams, K. M. 2012. Forest Nursery Pests Handbook. No. 680. US Department of Agriculture Forest Service, 212pp.

Nyeko. P. and Nakabonge, G. 2008. Occurrence of pests and diseases in tree nurseries and plantations in Uganda. A Study Commissioned by the Sawlog Production Grant Scheme (SPGS). 42pp.

Rebek, E. J. 2020. Management of insects and mites in tree nurseries. University of Oklahoma. Oklahoma Cooperative. Extension Fact Sheet CR-7092.16.