



World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Tree Seeds for Farmers

by

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DFID



Ministerie van
Buitenlandse Zaken

A Toolkit and Reference Source



World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

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Acronyms

ADRA	Adventist Development and Relief Agency
AgREN	Agricultural Research Network
AHI	African Highlands Initiative
ARDAP	Appropriate Rural Development Agriculture Programme
BAT	British American Tobacco
CBO	Community-based organization
CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CIG	Common interest groups
C-MAD	Community Mobilisation Against Desertification
COSOFAP	Consortium for Scaling-up Options for increasing Farm Productivity and incomes in western Kenya
DANIDA	Danish International Development Agency
DFID	Department for International Development, UK
DFSC	DANIDA Forest Seed Centre
DGAK	Dairy Goat Association of Kenya
ECOTRUST	Environmental Conservation Trust of Uganda
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer field school
FLD	Danish Centre for Forest, Landscape and Planning
FORRI	Forestry Resources Research Institute
FSA	Farming systems approach
FTC	Farmers' training centre
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HIV/AIDS	Human immunodeficiency virus/Acquired immune deficiency syndrome
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and communication technology
IFAD	International Fund for Agricultural Development
IFSP	Indonesia Forest Seed Project
IGCP	International Gorilla Conservation Project
IIRR	International Institution of Rural Reconstruction
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated pest management
IPPC	International Plant Protection Convention
ITFC	Institute of Tropical Forest Conservation
ISNAR	International Service for National Agricultural Research
ISSAAC	Improved Seed Systems for Agroforestry in African Countries
ISTA	International Seed Testing Association
ITFC	Institute of Tropical Forest Conservation
JICA	Japan International Cooperation Agency
KADFA	Kabale District Farmers' Association

KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
KEPHIS	Kenya Plant Health Inspectorate
KWAP	Kenya Wood Fuel Agroforestry Programme
LRC	Learning resource centre
M&E	Monitoring and evaluation
MIS	Market information system
NARO	National Agricultural Research Organisation, Uganda
NFA	National Forestry Authority
NGO	Non-governmental organization
NTSC	National tree seed centre
ODI	Overseas Development Institute
OFI	Oxford Forestry Institute
PFSA	Participatory farming systems analysis
PRA	Participatory rural appraisal
PRIME/West	Productive Resource Investments for Managing the Environment Program/Western region
PWRD	People with recovery and disabilities
RELMA	Regional Land Management Unit, World Agroforestry Centre (ICRAF)
REFSO	Rural Energy and Food Security Organisation
SOFEM	Social Forestry Extension Model
SURUC-CODEP	Sustainable Rural Christian Community Development Programme
SWTWS	South Western Towns Water and Sanitation
T&V	Training and visits
TATRO	Technology Adoption Through Research Organizations
TNA	Training needs assessment
TNI	Training needs identification
TOT	Training-of-trainers
TOTDOMEA	Testing Options and Training Partners in Participatory Tree Domestication and Marketing in East Africa
TTZ	Tetrazolium
TWAN	Two-Wings Agroforestry Network
UCRC	Ugunja Community Resource Centre
UGADEN	Uganda Agroforestry Development Network
UNSPPA	Uganda National Seed Potato Producers' Association
UPOV	International Union for the Protection of New Varieties of Plants
VVOB	Flemish Association for Development Cooperation and Technical Assistance
WIFIP	Women in Fishing Industry Project

Foreword

In order to successfully disseminate agroforestry technologies, various hurdles that currently limit the scaling-up process must be tackled. The lack of tree seed, seedling and other planting materials (tree germplasm) is a major constraint to the scaling up of agroforestry innovations. Sustainable production of high-quality germplasm for a wide range of agroforestry species is the basis of a successful scaling-up process. Institutional and organizational procedures that are adequate and conducive to large-scale production and distribution of agroforestry seed are also needed.

Seed and seedlings production and distribution should be a collaborative effort between local actors and stakeholders (including farmers, governmental organizations, non-governmental organizations (NGOs), community-based organizations (CBOs) and research organizations. No blueprint exists for strategies for scaling up seed production. Indeed, such strategies need to be specific to local conditions and should be based on links and collaboration between local actors. The private sector should be involved in developing sustainable seed and seedling production systems without compromising germplasm quality.

This Toolkit is part of the World Agroforestry Centre's (ICRAF's) scaling-up activities for agroforestry technologies. The Toolkit was developed to provide information to farmers about sustainable production and distribution of agroforestry seed and seedlings. Also included are issues that deal with seed quality, developing joint strategies for seed production and ways of introducing sustainability in seed production and distribution systems.

Although this Toolkit was developed for ICRAF's Trees and Markets thematic area in East and Central Africa, the information and resources herein can be utilized globally. Users are encouraged to adapt the materials provided in this Toolkit for extension and training activities with farmers.

The authors hope that this Toolkit will encourage users to recommend strategies that encompass quality, diversity and sustainability of tree seed production, and help bring together organizations that are involved in seed production.

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The comments and suggestions provided by future users of the Toolkit and other stakeholders during needs assessment workshops in Kabale (Uganda, 21–24 June 2004) and Kisumu (Kenya, 7–9 July 2004) are highly appreciated. The National Agricultural Research Organisation (NARO) of Uganda and the Uganda Agroforestry Development Network (UGADEN) organized the Kabale workshop, while the Consortium for Scaling-up Options for increasing Farm Productivity and incomes in western Kenya (COSOFAP) organized the Kisumu workshop.

Bashir Jama (ICRAF Regional Coordinator for East and Central Africa) indicated the need for a Toolkit on tree seed for farmers, while Tony Simons (Leader of ICRAF's Trees and Markets theme) gave overall support to the development of the Toolkit. Joseph Nyangon, Josina Kimotho and Evelyn Kang'ethe provided support that was very important in obtaining the draft and final versions of the Toolkit. Joseph also provided substantial support in developing electronic videos and the sharepoint site for the Toolkit.

The Toolkit includes a CD-ROM with resource materials on agroforestry tree seed and more general extension materials on agroforestry systems. We thank the developers of these resource materials for permitting us to include them in the Toolkit. Citation of the original source material is required for the resource materials.

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Macdonald Wesonga (ARDAP)

How this Toolkit was developed

The availability of tree germplasm, that is, propagation material such as seed, seedlings, or cuttings, was identified as one of the crucial elements in scaling up agroforestry technologies by ICRAF and its partner organizations (Cooper and Denning, 2002). Bashir Jama, the ICRAF Regional Coordinator of East and Central Africa, responded to this need by initiating the development of a Toolkit on agroforestry tree seed. The Toolkit would speed up the adoption of agroforestry technologies and recognize the crucial importance of germplasm, especially seed, in scaling up agroforestry.

The Toolkit was developed as a training tool that collaborating organizations, such as non-governmental organizations (NGOs) and community-based organizations (CBOs), and governmental organizations, such as national tree seed centres (NTSCs) and natural resource research institutes, could use during extension activities involving tree seed and seedlings.

In the initial development stages of the Toolkit, a review of the available extension materials on tree seed and tree planting was conducted. It was found that extension and training materials had primarily focused on the technical side of seed production. There was limited information on two important elements of successful seed production and distribution: (i) a network of collaborating institutions, as was highlighted by a DANIDA-funded project on the institutional nature of seed production in Kenya, Malawi and Burkina Faso; and (ii) links with the private sector, especially with associations of small-scale tree nursery operators and seed dealers. The benefits of collaborating with associations of tree nursery operators were highlighted by a Kenyan DFID-funded project in peri-urban Nairobi, Meru and Kisumu.

The lessons of both these projects, and ICRAF's other expertise in seed production and distribution, were included in the Toolkit to expand the information that was already available on tree seed. Since "the technical part of tree seed collection, production and distribution is easy and is basically 90% common sense" (Søren Moestrup, Forest and Landscape, 2004), the Toolkit fills important gaps in the available information that will assist tree seed collection, procurement and distribution initiatives.

The Toolkit is structured around a list of questions that specific actors in seed production and distribution might ask. The considered actors include centralized trees nursery operators, farmers who purchase seed, farmers who purchase seedlings, farmers who produce seed, non-profit organizations that produce seed, non-profit organizations that distribute seed, large private seed producers, formal seed dealers, informal seed dealers, governmental organizations, extension services and research organizations. During the first phase of the Toolkit's development, a list of questions that each of these actors

could ask was produced. These questions were then grouped into 19 chapters according to topics.

As the chapters of the Toolkit took shape, a CD-ROM was simultaneously developed. This electronic material contains the chapters of the Toolkit that can be used to develop extension and training materials for target audiences. The CD-ROM also contains a selection of the training and extension materials on tree seed and tree planting that were encountered during the initial review of existing materials. The authors and publishers of these materials have very kindly agreed these materials can be included. Users are encouraged to modify any of the provided materials, so long as the original source of the materials is acknowledged.

Feedback on the Toolkit will be highly appreciated. For example, useful additional materials for the CD-ROM are welcome. New questions or additional answers to questions that are already listed will be appreciated. Useful experiences on tree seed activities from farmers would be excellent additions to the Toolkit. Please send your feedback to ICRAF's Training Unit (reference: Tree Seeds for Farmers Toolkit) at PO Box 30677, GPO 00100 Nairobi, Kenya.

List of materials on the CD-ROM

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How to use this Toolkit

The Toolkit is arranged around a series of questions that are grouped in 19 chapters. The list of all the chapters and questions and the page number are listed on pages xvii to xxii.

You can access the material in two ways:

- Method 1: Pick the chapter that you are interested in from the table of contents at the beginning of the Toolkit.
- Method 2: Pick the question that you are interested in from the list of questions provided on pages xvii to xxii.

Each chapter starts with **summary answers**. If the summary answer is not satisfactory, go to the full contents of the chapter where the **complete answer** is provided.

At the end of each chapter some **references** are provided. References that are included on the CD-ROM are indicated by the symbol . Those references can be consulted directly from the CD-ROM for additional information. For two chapters, some **video clips** are included that further explain some technical procedures. These video clips are also listed as reference materials on the CD-ROM and are given the symbol .

If you do not have a specific chapter or question in mind, you could start by reading the first chapter of the Toolkit or reading the additional materials on the CD-ROM.

Figure I.1 shows a flowchart for the decisions that you might make while using the Toolkit.


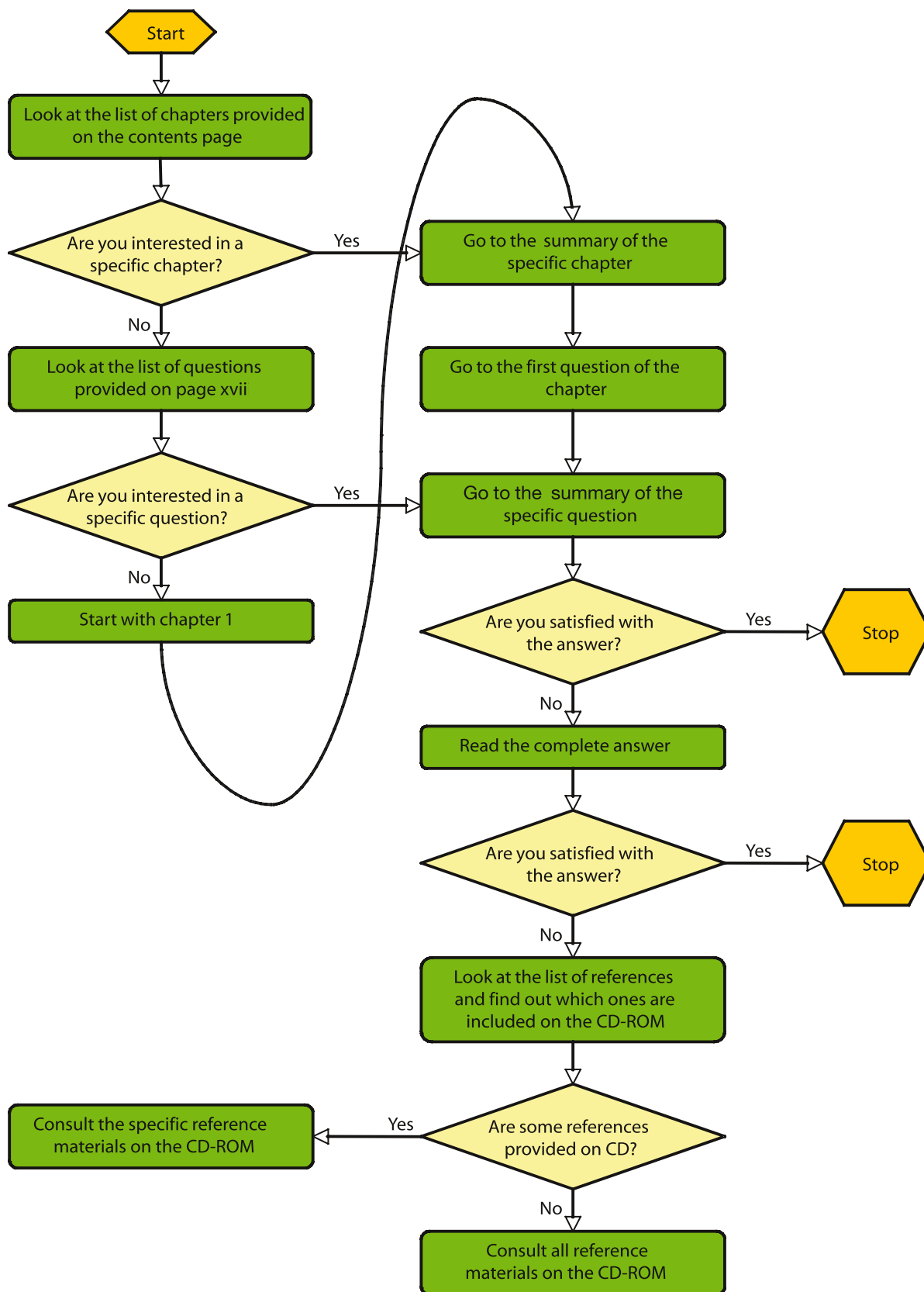
As an example, from the list of questions on page xix, you may be interested in the answer to question 8.7 *What are the basic principles of seed collection?* The table of contents indicates that chapter 8 starts on page 109. After consulting the summary at the beginning of the chapter, you may want to refer to page 115 for the complete answer to this question. If you are still not satisfied, then you could consult chapter 4 on seed collection from the *Guide to Handling of Tropical and Subtropical Forest Seed* () from the CD-ROM.

Figure I.1 Decision tree on how to use the Toolkit



Detailed list of questions

PART I: Strategies for scaling up seed production

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1.2 What is a seed system?	3
1.3 What are the key elements of a seed and seedling strategy?	3
1.4 Why are sources of reproductive material crucially important to seed strategies?	3
1.5 What different types of seed systems exist?	4
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PART I:

S **trategies for scaling-up seed production**

Chapter 1:

Seed Production and Distribution Strategies

Summary

1.1 Why are strategies needed for seed production and distribution?

Seed is produced and distributed by people in many different ways. As a consequence, there are many potential actors and many different roles that these actors play. A well-functioning seed system depends on good collaboration between the various actors. Your degree of success in seed production and distribution will increase if you prepare a strategy that takes into account the constraints and opportunities of all the actors and their roles.

More on page 6

1.2 What is a seed system?

A seed system is made up of organizations and individuals, also known as actors, who perform different functions within an institutional setting to produce seed. These functions include breeding, multiplication, processing, storage, distribution and marketing of seed. Information exchange is particularly important for the optimal functioning of seed systems.

More on page 6

1.3 What are the key elements of a seed and seedling strategy?

A seed and seedling strategy defines the roles of various actors. A good strategy results in a well-functioning system that sustainably provides good-quality seed and seedlings. The roles of various actors are: seed sources management, seed procurement methodology and seed distribution.

More on page 8

1.4 Why are sources of reproductive material crucially important to seed strategies?

Reproductive materials of good genetic quality are crucial to successful agroforestry systems because the reproductive material source is the first link in the production and distribution chain. Therefore, the reproductive material source determines the efficiency of the seed system and the maintenance of genetic quality. In many cases, inferior quality seed and vegetative reproductive material have been introduced into agroforestry systems with negative long-term effects on the genetic quality of material available to farmers.

There are five general types of sources of reproductive material, four types are from seed and one type is from vegetative material. The sources are: natural forest, farmland, seed orchards, plantations and vegetative propagation. The genetic quality of seed is determined by the quality of the source, and also by the seed collection method from the seed source.

More on page 9

1.5 What different types of seed systems exist?

The tree seed production and distribution chain can be split into three major types of actors that are linked: (i) seed source owner, (ii) seed procurer and (iii) seed distributor. Each of these three actors can be organized in a centralized way (one or a few organizations control the actors) or in a decentralized way (many organizations control the actors). The advantages and disadvantages of the various combinations of centralized and decentralized organization are different for the five sources of reproductive material.

More on page 10

1.6 What is the role of marketing and enterprise in strategies?

There is no blueprint for strategies that the different types of actors should make to become most successful within a seed system, since these strategies depend very much on the system's rules. Different combinations of functions can be taken by the private and public actors within a particular seed system. Instead of asking, "Should the national tree seed centres (NTSCs), research organizations and NGOs produce and distribute seed centrally?" it may be more productive to ask, "How and to what extent can NTSCs, research organizations and NGOs support the development of a market for seed and seedlings?"

More on page 12

1.7 What are the general recommendations for developing strategies for production and distribution of crop seed?

Differences between the biologies of crop seed and tree seed influence their production and distribution. However, the two systems have a major similarity: farmers do not generally have access to suitable varieties of good-quality seed. The reform of agricultural seed systems usually includes suggestions to reform policy; to increase the effective demand for improved varieties; to decrease the cost of seed production and distribution; and to improve infrastructure, rules and regulations.

More on page 13

1.8 What are the possible roles of actors in production chains?

The activities in each of these phases can be performed, supported and controlled in various ways by different actors. An actual strategy will be based on the definition of the roles of the various actors. There are usually pros and cons for the role a particular actor fulfils. Ideally, the seed strategy should be based on discussions held with the various actors so that they can collaborate efficiently. There is no model seed strategy that will be the best for every location. The actors should therefore decide on how quality seed and seedlings can be produced sustainably in their target areas.

More on page 15

Introduction

The lack of tree seed is often cited as a key constraint to the adoption of new agroforestry technologies, alongside problems of seed quality and lack of a broad diversity of species. This means that, although there is demand for seed by farmers, they are unable to obtain access to it, or there is inadequate supply.

The problem of inadequate supply of and lack of access to tree seed is similar to the constraints facing agricultural crops in Africa, where farmers have limited access to improved seed of a wide range of suitable crop varieties, and where seed production and marketing are major limitations for poor farmers.

1.1 Why are strategies needed for seed production and distribution?

Seed is produced and distributed in many different ways ranging from a farmer collecting seed from trees on the farm through to a multinational corporation producing and distributing genetically modified seed to large-scale plantations across the world.

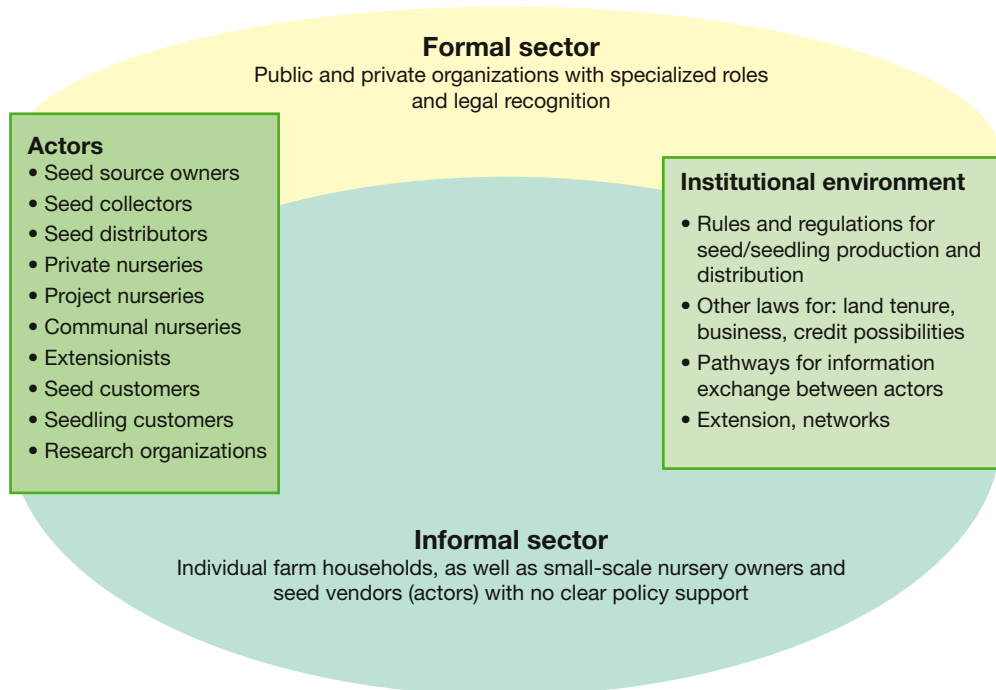
There are many ways to organize seed production and distribution. There are also many potential actors and many different roles that these actors can play. A well-functioning seed system depends on good collaboration between the various actors. Whether you are a small nursery owner selling seedlings; an NGO trying to start up a tree planting project; or a government organization wishing to improve farmers' livelihoods through agroforestry, your degree of success will increase by preparing a strategy that takes into account the constraints to and opportunities for seed production and distribution.

1.2 What is a seed system?

It is useful to look at seed production and distribution as a **seed system** that is composed of **actors** who may be organizations and individuals involved in different seed system **roles** or **functions**. These functions include breeding, multiplication, processing, storage, distribution and marketing. The descriptions of the tree seed system and information in this Toolkit are adapted from the description of crop seed systems in Maredia et al. (1999) and Tripp and Rorbach (2001); the terms are commonly used in the literature on crop seed systems.

The seed system illustrated in figure 1.1 includes informal (or traditional) and formal sectors. The **informal sector** is made up of individual farm households, as well as small-scale nursery owners and seed vendors (actors) with no clear policy support, each carrying out most seed system functions on their

Figure 1.1 Smallholder tree seed system



own with little or no specialization. The **formal sector** is made up of public and private organizations (actors) with specialized roles in supplying new tree species and varieties. The **institutional environment** includes not only the formal laws and regulations, but also the informal conventions of market behaviour and social interchange.

Information exchange is particularly important, and seed systems can often be made more effective if the conditions for access to and exchange of information among large numbers of farmers are improved.

Three types of information are important:

- i) Technical information acquaints farmers with the advantages and disadvantages of various production options and informs plant breeders, public agencies and merchants about farmers' requirements.
- ii) Economic information determines what inputs farmers are willing to use and what products are brought to market.
- iii) Information about the expected performance of partners (their reputations and trustworthiness) determines the willingness of farmers, merchants and consumers to enter into transactions.

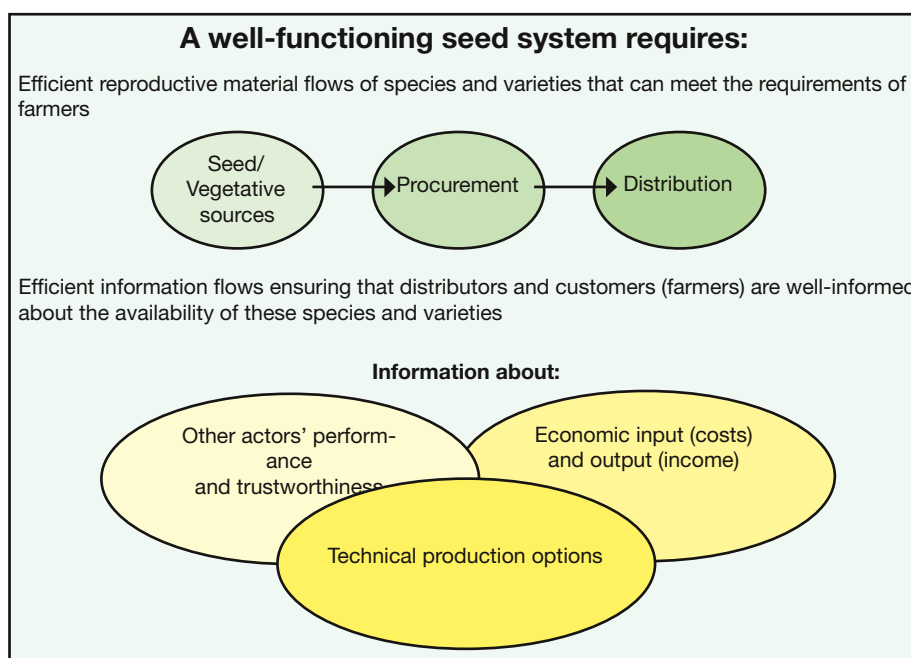
Efficient institutions must be available to facilitate the transmission of all three types of information.

1.3 What are the key elements of a seed and seedling strategy?

A seed and seedling strategy defines the roles of the various actors. A good strategy will result in a well-functioning system, that is, a system that will provide seed and seedlings of good quality in a sustainable manner. A well-functioning seed/seedlings system can be described as “one that uses the appropriate combination of formal, informal, market and non-market channels to stimulate and efficiently meet farmers’ evolving demand for quality seed and seedlings.” Species and varieties that can meet the requirements of farmers should be available and farmers should be well-informed about the availability of these species and varieties. Figure 1.2 illustrates the main links and information flow in a well-functioning tree seed system.

To describe a strategy, the roles of the various actors can be defined in terms of seed source management, procurement methodology and distribution. The type of seed source and the type of ownership are important characteristics of **seed sources**. **Procurement methodology** includes all activities related to seed collection, transport, processing, cleaning, testing and storing. The ways and means through which seed is distributed or sold define the **distribution/sales methodology**.

Figure 1.2 Efficient flow of reproductive material and information within a well-functioning system



1.4 Why are sources of reproductive material crucially important to seed strategies?

The availability of good sources of reproductive material is a prerequisite to successful agroforestry systems. In many cases, inferior quality seed has been introduced into agroforestry systems without regard for the long-term genetic quality of material that will be made available to farmers.

Seed/vegetative sources can be established in several different ways, depending on the biological characteristics of species and the organizational setup of production and distribution. The seed/vegetative source is the first link in the seed production and distribution chain and to a large extent determines the efficiency of the seed system, and how genetic quality is maintained.

Sources of reproductive material have many names, but can all be categorized into five general types. Four types are from seed and one type is from vegetative material (see table 1.1). In most practical situations, the choice of species determines the type of seed source that can be utilized and often short-term economic criteria determine which type is actually used.

The genetic quality of seed is determined by the quality of the seed source and the way seed is collected (number of trees collected from and the relative quality of trees collected from). Subsequent handling (seed processing, seed storage and seed distribution) influences the physiological and physical qualities of the seed. Testing seed for germination capacity measures the physiological quality, but it does not measure the genetic quality [in many countries tree seed testing (testing of germination capacity) is used as an argument for why production and distribution of seed should be wholly centralized. Such an argument disregards the more important aspect of genetic quality (see chapter 7).]

Table 1.1 General sources of reproductive material

Source type	Brief description
Natural forest	Natural vegetation, ranging from high forest to woodlands
Farmland	Tree species on farms – planted or remnants of natural vegetation
Plantations	Trees planted in a plantation or a woodlot
Seed orchards	Trees planted in a plantation or woodlot, specifically for seed production
Vegetative propagation	Grafts, stem cuttings, micro cuttings, or somatic embryos propagated from selected clones or seedlings

There are important social and economic issues to be considered in the production and distribution chains. For instance, who gains experience and ownership in the production, procurement, and distribution of seed and seedlings?

Seed sources (from seed or vegetative material) determine the production and distribution chain of seed and seedlings. The type of seed source determines to a large extent what types of source ownership, procurement, and distribution are practically feasible. In a given situation, the availability of a particular species will determine what type of seed source(s) can be deployed in the short and long terms.

For example, for many high-value indigenous timber species the only high-quality seed sources will be ‘natural forest’ (although the inferior choice of ‘vegetative propagation’ of unknown material with very limited genetic variation is sometimes chosen as a source).

1.5 What different types of seed systems exist?

The production of seed (and vegetative material) can conveniently be broken into three major links in the production and distribution chain (see figure 1.3). The important issue for each link in the chain is who controls the link and thereby gains experience and participates in the market as an actor.

As described above, tree seed production and distribution chains can be split up into three major types of actors: (i) seed source owner, (ii) seed procurer and (iii) seed distributor. Each of these three links can be organized in a centralized way (one or a few organizations control the actors) or in a decentralized way (many organizations control the actors).

Table 1.2 shows the combinations of centralized or decentralized organization of the actors in a tree seed production and distribution chain. The combinations CCD, CDC, and DCD are theoretical only and are not used.

Figure 1.3 Production and distribution chain

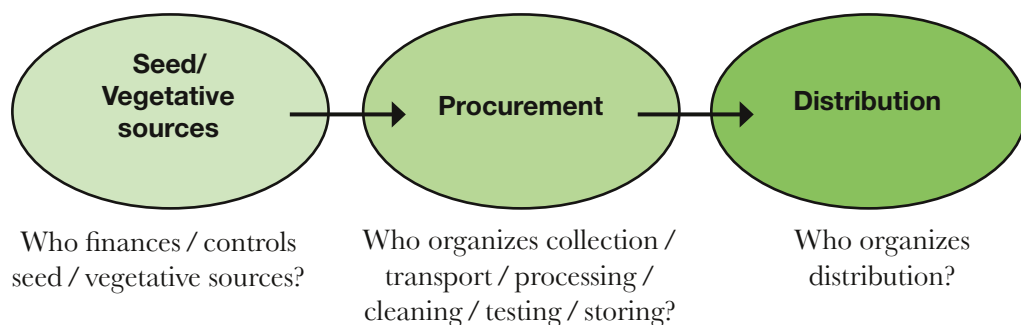


Table 1.2 Principal seed supply chains: combinations of centralized (C) or decentralized (D)

Seed supply chains	Example of operational seed supply systems
CCC	NTSCs, national agricultural research organizations (NAROs), NGOs
CCD	Not applicable
CDD	Community-based organizations (CBOs) and seed dealers collecting and distributing seed from NTSC-owned seed sources
CDC	NTSCs contracting individual farmers to collect seed from government owned natural forests
DDD	CBOs, and seed vendors collecting and distributing seed from CBO-owned or farmland seed sources
DDC	NTSCs, NAROs or NGOs buying and distributing seed from CBO-owned or farmland seed sources.
DCC	NTSCs, NAROs or NGOs collecting and distributing seed from CBO-owned or farmland seed sources
DCD	Not applicable

Key: First letter – seed source; Second letter – seed procurement; Third letter – seed distribution

The advantages and disadvantages of the various combinations of centralized and decentralized organization are distinct for the five types of seed sources. For example, collection of quality seed from natural forest seed sources will, in most cases, be handled most efficiently by a centralized production and distribution chain. Collection of quality seed from farmland seed sources will be handled most efficiently in decentralized chains.

It is likely that most trees in a farmland have their origin in a non-commercial DDD model. This model works through slow diffusion and is not a reliable model for the fast introduction of high-quality material to farmers. The commercial DDD model is potentially the most efficient model for introducing high-quality material to farmers, but it is rarely used and would require substantial changes to the modus operandi of governments, NGOs and projects. Such a process would require relatively large support of information flow between producers, distributors and consumers.

The DDC model is probably the most commonly used model by NGOs, where NGOs organize seed collection from farmland and then distribute free seed to farmers. The use of this model is likely to be one of the biggest obstacles to a successful implementation of the commercial DDD model because free seed undermines commercial efforts to sell seed.

1.6 What is the role of marketing and enterprise in strategies?

We have argued above that a well-functioning seed system requires that: (i) the actors in the system are able to track the farmers' evolving demand for seed and seedlings, (ii) the farmers are well-informed customers and (iii) efficient and sustainable production and distribution chains for the species and varieties in demand exist. There is no blueprint for what strategies the different actors should follow to become most successful within a seed system, since this depends very much on the rules of the system.

Table 1.3 illustrates the different combinations of functions that the private and public actors can take within a seed system. Often, seed systems are seen as either centralized (NTSCs) or decentralized (NGOs or small-scale producers), but it is more productive to look at the roles the different actors could play. Therefore instead of asking "Should the NTSCs, research organizations and NGOs produce and distribute seed centrally?" it may be more productive to ask "How, and to what extent, can NTSCs, research organizations and NGOs support the development of a market for seed and seedlings?"

Table 1.3 Marketing and enterprise roles within a seed system

Sector strategies	NTSC	CGIAR*	NGOs/projects	Extension
Support to potential customers	Direct production or market enabler	Direct production or market enabler	Direct production or market enabler	Advise on technologies and support market development
Seed/seedling source networks				
Seed/seedlings producers	Project clients or market players	Project clients or market players	Project clients or market players	
Seed traders	Competition or facilitation	Undermine or facilitation	Undermine or facilitation	
Associations	Competition or facilitation	Undermine or facilitation	Undermine or facilitation	
Species	How to diversify	How to diversify	How to diversify	
Information network and marketing	Who and how and for whom to develop	Who and how and for whom to develop	Who and how and for whom to develop	
Tree nurseries as an enterprise	Kinds of support	Kinds of support	Kinds of support	
Seed as an enterprise	Kinds of support	Kinds of support	Kinds of support	

* Consultative Group on International Agricultural Research

In many countries the NTSC has the mandate for establishing seed sources and controlling seed distribution within a centralized seed system. However, the role of several NTSCs is changing from that of sole provider of seed to that of facilitator in developing a private seed and seedling distribution system (a decentralized seed system). Actors should therefore find out how the government is encouraging seed production and distribution.

One of the most important constraints to the development of a private seed production and distribution system is free handouts of seed and seedlings. Before providing free handouts the actor should first consider the impact of this free distribution of seed to the nursery business in an area. From the opposite perspective, if an actor is planning to set up a business, the risk should be considered since free handouts may destroy the business.

Some of the most important criteria for success in providing good-quality seed and seedlings are access to material of good genetic quality and channels for promoting the advantages of using the high-quality material. An important part of an actors' strategy should therefore focus on how to promote the actor's products. Depending on the particular institutional support available in an area (and country), you may be able to get support from various organizations for both seed sourcing and the promotion of your material.

One of the lessons learned from the agricultural seed sector is that technical support to seed production at village level usually fails to lead to viable seed enterprises. Major reasons for failure are that there is simply not sufficient demand for seed at the village level, and most of the transaction costs are covered by NGOs and projects, making long-term seed production unsustainable.

1.7 What are the general recommendations for developing strategies for production and distribution of crop seed?

There are differences between the biologies of crop seed and tree seed which influence how they are produced and distributed. The main similarity is that farmers in general do not have access to good-quality germplasm of suitable varieties. The major difference is that most crops are annual, while trees and shrubs are perennial and take longer to mature and to produce seed for the next generation; for many crops, the seed multiplication ratio (grain: seed sown) is very high and seed is a considerable production cost. The multiplication ratio ranges from around 10 for potatoes to around 240 for pearl millet. For practically all trees and shrubs, seed is a very small part of the cost of production of the tree-based crop – in plantation forestry the cost of seed is usually about two percent of the establishment costs.

The general recommendations for reform of agricultural seed systems are equally relevant for agroforestry seed systems and so are detailed below.

Suggestions for policy reform

- Re-examine the objectives of the seed system and evaluate which combinations of formal, informal, market and non-market channels can most efficiently meet farmers' evolving demand for quality seed, and how appropriate varieties can best be introduced into market channels that can supply varieties and information about these varieties to farmers.
- Redefine the role of government in the systems from a purely controlling role towards an enabling role; a new collaboration between NTSCs, NAROs and the private sector should be established.
- Redefine the role of government agencies. In particular, how public and private investments can complement each other, how various levels of seed production – from breeding to commercial seed delivery – can best be supported, and how emphasis can be shifted from regulation to consumer education.
- If seed system development is to be sustainable, larger efforts are required to build local marketing institutions and government should invest in supporting the development of a viable commercial seed sector for rural retailers. Such support should take into account the high transaction costs incurred when dealing with larger numbers of dispersed and relatively isolated small-scale farmers.

Some specific recommendations for improving agricultural seed systems that could be considered for tree seed and seedlings systems are:

1.7.1 Increasing effective demand for improved varieties among smallholder farmers

- Build the capacity to move from homogeneous seed recommendations to the development and dissemination of varieties targeted to specific agroecological zones and the needs of different groups of farmers.
- Strengthen extension programmes to increase farmer knowledge about the benefits of using new seed; transmit information about farmer preferences to researchers' initiatives that improve post-harvest product utilization, expand output markets and lower production risks.

1.7.2 Decreasing the cost of seed production and distribution

- Promote the production of different seed commodities by seed suppliers likely to have a comparative advantage in producing them.
- Train new seed producers and reduce the cost of doing business for formal and informal seed sector actors.
- Ensure that regulatory authorities consider how their standards and procedures may affect the costs of seed. Alternative seed quality control systems like 'truth in labelling' may contribute more to the development of rural markets than insistence on stricter quality standards.

1.7.3 Improving infrastructure, rules and regulations

- Improve transport and information infrastructure, and revise or enforce laws and regulations to lower the risks and costs of doing business in the seed sector, especially for smaller firms and farmer groups.
- Revise seed regulations in a way that facilitates the development of a heterogeneous, competitive group of seed producers while protecting the rights of all producers and consumers. Many regulations were fashioned for formal sector seed enterprises and discourage farmer-based seed production, for example, stringent variety release procedures, plant breeder's rights and plant variety protection laws.
- Consider whether the international standards [set by International Plant Protection Convention (IPPC), International Seed Testing Association (ISTA), and International Union for the Protection of New Varieties of Plants (UPOV)], which are viewed as ideal guidelines for trade on the formal, commercial market, are practical to implement across sub-Saharan Africa. Cheaper seed of adequate quality may be more marketable than costly seed of high quality.

1.8 What are the possible roles of actors in production chains?

The activities in each of the links in the production–procurement–distribution chain can be carried out by different actors and can be supported and controlled in various ways by the same or other actors. The following tables illustrate the possibilities for each production phase and indicate the pros and cons for actors being responsible for each action. The pros and cons written in the tables are relative statements, but are intended to stimulate discussion.

An actual strategy will be based on defining the roles of the various actors. Ideally, the seed strategy should be based on discussions held with the various actors so that they can collaborate efficiently. There is no model seed strategy that will be the best for every location. The actors should therefore decide on how quality seed and seedlings can be produced in a sustainable way in their target areas.

The following are links in the production–procurement–distribution chain: **seed source control**, table 1.4; **seed procurement** (collection), table 1.5; **seed procurement** (processing), table 1.6; **seed procurement** (storage), table 1.7; **seed procurement** (testing), table 1.8; and **seed distribution**, table 1.9.

Table 1.4 Pros and cons of responsibilities for seed source control activities by various actors

Pros and cons in terms of:				
Seed source control	Source type/ownership/location and role of source control	Cost, quality of seed and sustainability	Quality of documentation, regulation and certification	
			Types of support	
NTSC	Any type except on private land (farmland) Technical advice to NGOs Seed source certification	<i>Pros:</i> Quality assured <i>Cons:</i> Limited number of seed sources possible due to cost of maintenance and protection compared to income Local people have little incentive to protect source	<i>Pros:</i> Documentation and certification part of NTSC procedure (but inadequate criteria for farmland and natural forest) <i>Cons:</i> Information not widely available to farmers	Direct government/donor support required for maintenance and protection
CGIAR, NAROs, Forestry Department, National Parks	Any type on government land Natural forest through government Support introduction of species to farmland/community land	<i>Pros:</i> Quality assured in principle <i>Cons:</i> Limited number of seed sources possible due to cost of maintenance and protection compared to income Local people have little incentive to protect source	<i>Pros:</i> Documentation good (but inadequate criteria for farmland and natural forest) <i>Cons:</i> Information not generally available to farmers	Direct government/donor support required for maintenance and protection
NGOs/projects	Support introduction of species to farmland/community land (DDD combination) DDC combination (destroys DDD model) No direct access to natural forest	<i>Pros:</i> Cost covered by NGOs <i>Cons:</i> Quality not always up to standard Sustainability not assured System unlikely to continue once project pulls out	<i>Pros:</i> If DDD combination, NGOs can help set criteria for small-scale producers <i>Cons:</i> If DDC combination, little concern for documentation; no certification schemes	Cost covered by NGOs/donor for project duration
Private seed traders/associations	On private land – support DDD model No direct access to natural forest	<i>Pros:</i> Easy access. Many sources possible <i>Cons:</i> Genetic quality may be compromised in farmland Require commercial networks for sustainability (or out-grower schemes)	<i>Pros:</i> Documentation could be widely available if supported <i>Cons:</i> Little concern for documentation; no certification schemes	Rarely supported by NGOs/donors
Private nursery operators/associations	On private land – support DDD model No direct access to natural forest	<i>Pros:</i> Easy access for private seed sources Many sources possible <i>Cons:</i> Genetic quality may be compromised in farmland Require commercial networks for sustainability (or out-grower schemes)	<i>Pros:</i> Documentation could be widely available if supported <i>Cons:</i> Little concern for documentation; no certification schemes	Rarely supported by NGOs/donors
Farmers/groups/village use and sale	On private and community land No direct access to natural forest	<i>Pros:</i> Easy access Many sources possible <i>Cons:</i> Genetic quality may be compromised in farmland Require commercial networks for sustainability (or out-grower schemes)	<i>Pros:</i> Documentation could be widely available if supported <i>Cons:</i> Little concern for documentation; no certification schemes	Rarely supported by NGOs/donors

Table 1.5 Pros and cons of responsibilities for seed procurement (collection) activities by various actors

Seed collection by whom	Method of collection per type*	Pros and cons in terms of:			Types of support
		Cost and safety	Quality of documentation, regulation and certification	Demand/supply	
NTSC	<ol style="list-style-type: none"> 1. Directly or sub-contracted 2. Directly or sub-contracted 3. Directly by professional climbers 4. Directly or sub-contracted 	<p><i>Pros:</i> Safe collection from tall trees <i>Cons:</i> Very expensive</p>	<p><i>Pros:</i> Documentation and certification part of NTSC procedure <i>Cons:</i> Information not widely available to farmers</p>	<p>Bureaucratic and no process for meeting demand and supply</p>	<p>Direct government/donor support required</p>
CGIAR, NAROs, Forestry Department, National Parks	<ol style="list-style-type: none"> 1. Directly or sub-contracted 2. No professional climbers 3. No professional climbers 4. Directly or sub-contracted 	<p><i>Pros:</i> Could support safe climbing <i>Cons:</i> Very expensive</p>	<p><i>Pros:</i> Documentation and certification could be done <i>Cons:</i> Information not widely available to farmers</p>	<p>Bureaucratic and no process for meeting demand and supply</p>	<p>Direct government/donor support required</p>
NGOs/projects	<ol style="list-style-type: none"> 1. Directly or sub-contracted 2. No professional climbers 3. No professional climbers 4. Directly or sub-contracted 	<p><i>Pros:</i> Could support safe climbing <i>Cons:</i> Very expensive</p>	<p><i>Pros:</i> Documentation and certification rarely done <i>Cons:</i> No documentation systems</p>	<p><i>Pros:</i> Demand/supply calculations sometimes done <i>Cons:</i> Push supply; localized – not wide, often free seed or seedling</p>	<p>Direct donor support required</p>
Private seed traders/associations	<ol style="list-style-type: none"> 1. Directly (from farmland) 2. Directly (from farmland) 3. No professional climbers 4. Directly 	<p><i>Pros:</i> Inexpensive <i>Cons:</i> Lack of documentation; lack of safety; lack of know-how</p>	<p><i>Pros:</i> Certification scheme as part of marketing <i>Cons:</i> No documentation systems available/accepted by government</p>	<p><i>Pros:</i> Market can be developed. <i>Cons:</i> Market imperfect, few species available</p>	<p>Sales could justify costs</p>
Private nursery operators/associations	<ol style="list-style-type: none"> 1. Directly (from farmland) 2. Directly (from farmland) 3. No professional climbers 4. Directly 	<p><i>Pros:</i> Inexpensive <i>Cons:</i> Lack of documentation; lack of safety; lack of know-how</p>	<p><i>Pros:</i> Certification scheme as part of marketing <i>Cons:</i> No documentation systems available/accepted by government</p>	<p><i>Pros:</i> Market can be developed <i>Cons:</i> Market imperfect, few species available</p>	<p>Sales could justify costs</p>
Farmers/groups/village use and sale	<ol style="list-style-type: none"> 1. Directly (from farmland) 2. Directly (from farmland) 3. No professional climbers 4. Directly 	<p><i>Pros:</i> Inexpensive <i>Cons:</i> Lack of documentation; lack of safety; lack of know-how</p>	<p><i>Pros:</i> Certification scheme as part of marketing <i>Cons:</i> No documentation systems available/accepted by government</p>	<p><i>Pros:</i> Market can be developed <i>Cons:</i> Market imperfect, few species available</p>	<p>Own use or sales could justify costs</p>

* Key to type of species: 1. Agroforestry; 2. Exotic timber; 3. Indigenous timber/medicinal; 4. Cloned fruit trees/medicinal

Table 1.6 Pros and cons of responsibilities for seed procurement (processing) activities by various actors

Seed processing by whom	Pros and cons in terms of:			Types of support
	Level of processing possible/types of species that can be processed	Cost and species covered	Quality of documentation, regulation and certification	
NTSC	State-of-the-art possible	<i>Pros:</i> All species and large volumes <i>Cons:</i> Centralized and expensive	<i>Pros:</i> Documentation part of NTSC procedure <i>Cons:</i> High-tech processing may not be required	Direct government/donor support required
CGIAR, NAROs, Forestry Department, National Parks	For nucleus amounts	<i>Pros:</i> For nucleus amounts <i>Cons:</i> Centralized and expensive	<i>Pros:</i> Documentation could in principle be done (but rarely in practice) <i>Cons:</i> Information not widely available to farmers	Direct government/donor support required
NGOs/projects	Easy species only, lack of know-how on moisture control and pest control	<i>Pros:</i> Cheaper than NTSC/CGIAR <i>Cons:</i> Limited species range	<i>Pros:</i> Documentation could in principle be done (but rarely in practice) <i>Cons:</i> Information not widely available to farmers	Direct donor support required
Private seed traders/associations	Easy species only, lack of know-how on moisture control and pest control	<i>Pros:</i> Inexpensive. <i>Cons:</i> Limited access to information	<i>Pros:</i> Inexpensive <i>Cons:</i> Lack of documentation	Sales could justify costs
Private nursery operators/associations	Easy species only, lack of know-how on moisture control and pest control	<i>Pros:</i> Inexpensive. <i>Cons:</i> Limited access to information	<i>Pros:</i> Inexpensive <i>Cons:</i> Lack of documentation	Sales could justify costs
Farmers/village groups/village use and sale	Easy species only, lack of know-how on moisture control and pest control	<i>Pros:</i> Inexpensive. <i>Cons:</i> Limited access to information	<i>Pros:</i> Inexpensive. <i>Cons:</i> Lack of documentation	Own use or sales could justify costs

Table 1.7 Pros and cons of responsibilities for seed procurement (storage) activities by various actors

Seed storage by whom	Pros and cons in terms of:			Types of support
	Level of storage possible/ types of species that can be stored	Quality of documentation, regulation and certification	Research on storage of new species	
NTSC	State-of-the-art possible All orthodox and many intermediate/recalcitrant	<i>Pros:</i> Well documented <i>Cons:</i> Expensive, difficult to access for farmers	State-of-the-art possible	Direct government/donor support required
CGIAR, NAROs, Forestry Department, National Parks	State-of-the-art possible All orthodox and many intermediate/recalcitrant	<i>Pros:</i> Well documented <i>Cons:</i> Expensive, difficult to access for farmers	State-of-the-art possible	Direct government/donor support required
NGOs/projects	Short-term storage for orthodox, few if any intermediate	<i>Pros:</i> Accessible to farmers in local areas <i>Cons:</i> Limited documentation	Rarely done	Direct donor support required
Seed traders/ associations	Short-term storage for orthodox	<i>Pros:</i> Accessible to farmers <i>Cons:</i> No documentation, not supported by NTSC	Rarely done, if at all	Sales could justify cost NTSC could support
Nursery operators/ associations	Short-term storage for orthodox	<i>Pros:</i> Accessible to farmers <i>Cons:</i> No documentation, not supported by NTSC	Rarely done, if at all	Sales could justify cost NTSC could support
Farmers/groups/ village use and sale	For own use or sale	<i>Pros:</i> Accessible to farmers. <i>Cons:</i> No documentation, not supported by NTSC	Rarely done, if at all	Use/sales could justify cost NTSC could support

Table 1.8 Pros and cons of responsibilities for seed procurement (testing) activities by various actors

Seed testing by whom	Pros and cons in terms of:			Types of support
	Level of processing possible/types of species that can be processed	Cost and species covered	Research on testing of new species	
NTSC	State-of-the-art possible	<i>Pros:</i> Ensures quality <i>Cons:</i> Cumbersome, inhibits market development	State-of-the-art possible	Direct government/donor support required
CGIAR, NAROs, Forestry Department, National Parks	State-of-the-art possible	<i>Pros:</i> Ensures quality <i>Cons:</i> Only small quantities	State-of-the-art possible	Direct government/donor support required
NGOs/projects	Usually depends on NTSC for testing	<i>Pros:</i> NTSC ensures quality or own test could ensure quality <i>Cons:</i> Cumbersome, often not done	Rarely develop facilities	Direct donor support required
Private seed traders/associations	With government support: Quality assurance (QA)/Truth in labelling (TiL) possible	<i>Pros:</i> QA and TiL possible <i>Cons:</i> Only if support from NTSC	Not applicable	Support by government/CGIAR for market development
Private nursery operators/associations	With government support: QA/TiL possible	<i>Pros:</i> QA and TiL possible <i>Cons:</i> Only if support from NTSC	Not applicable	Support by government/CGIAR for market development
Farmers/groups/village use and sale	For own use	<i>Pros:</i> QA and TiL possible <i>Cons:</i> Only if support from NTSC	Not applicable	Support by government/CGIAR for market development

Table 1.9 Details of seed distribution activities by various actors

Seed distribution by whom	Reasons for /types of distribution for different types of species	Quality of documentation, regulation and certification	Research on distribution of new species	Types of support
NTSC	<ol style="list-style-type: none"> 1. Establishment of seed sources 2. Establishment of seed sources 3. Species mobilization in landscapes 4. Establishment of new clonal production 	Publish documentation requirements, support regulation and development of certification	Carry out research	Support by government/donors
CGIAR, NAROs, Forestry Department, National Parks	<ol style="list-style-type: none"> 1. Establishment of new seed sources 2. Establishment of new seed source 3. From NTSC for mobilization in landscapes 4. Establishment of new clonal production 	CGIAR and NAROs: Develop documentation for new species Forestry Department and National Parks: Document distribution of their species	Carry out research	Support by government/donors
NGOs/projects	<ol style="list-style-type: none"> 1. Establishment of new seed sources 2. Establishment of new seed sources 3. From NTSC for mobilization in landscapes 4. Establishment of new clonal production 	Support smallholder private sector by ensuring quality	Disseminate results on new species	Support by donors
Private seed traders/associations	<ol style="list-style-type: none"> 1. Sale 2. Sale 3. From NTSC 4. Sale 	Use documentation, regulations and certification as part of marketing	Utilize new species	Support by government/donors/CGIAR/NAROs
Private nursery operators/associations	<ol style="list-style-type: none"> 1. Sale 2. Sale 3. From NTSC 4. Sale 	Use documentation, regulations and certification as part of marketing	Utilize new species	Support by government/donors/CGIAR/NAROs
Farmers/groups/village use and sale	<ol style="list-style-type: none"> 1. Sale 2. Sale 3. From NTSC 4. Sale 	Use documentation, regulations and certification as part of marketing	Utilize new species	Support by government/donors/CGIAR/NAROs

* Key to type of species: 1. Agroforestry; 2. Exotic timber; 3. Indigenous timber/medicinal; 4. Cloned fruit trees/medicinal

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Chapter 2:

Research

Summary

2.1 Why is research on tree seed systems needed?

Within a well-functioning seed system, both seed and certain information about the seed is distributed to end users. Three types of information are important: **technical information**, **economic information** and **information about partners within networks**.

Research is needed within all three types of information, because we do not know everything yet, and because research may help to improve farmers' livelihoods through use of trees. As a key guideline, research should only be conducted when information is not available, and when it is important to know something.

There are two main reasons why we do not know everything yet. The first reason is that a very large number of tropical tree species are used by farmers, and that complete technical information (see Part II) is only available for some of these species. The second reason is that tree seed systems can be organized into various ways (see chapter 1), but to date research has mainly been conducted in the context of centralized systems. Therefore, a need exists to conduct research on species and on organizational systems.

The type of research that is needed is mainly on appropriate technologies, participatory approaches, production chain analyses and information pathways.

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2.2 Who needs to conduct tree seed research?

In many tropical countries a national tree seed centre (NTSC) has been established with the sole mandate for collecting, producing and distributing tree seed. These NTSCs have been very active in conducting research on the physiology of seed and seedlings, and use of appropriate species and provenances. Since NTSCs are limited in their capacity and have not conducted research on many indigenous species, other actors of the tree sector are encouraged to conduct small-scale research if and when there are particular problems with a particular species.

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2.3 What technical research is needed?

Seed quality needs to be maintained from the moment the seed is collected to the moment it is provided to the final user (see Part II). When information is not available on a particular species and when this species suffers from a reduction in quality, then research needs to be conducted. Research can be conducted on seed sources, seed collection, seed processing, seed testing and seed storage. Research will either focus on genetic quality or physiological and physical qualities.

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2.4 What technical research is needed on physiological and physical qualities of tree seed?

The research on the physiological and physical qualities of tree seed that has been carried out has been based within the context of a centralized tree system. Within this context, the central institution (often the NTSC) has access to laboratory facilities for testing seed, cold storage facilities for optimal seed storage and well-trained human capacity for seed collection and seed handling. In decentralized seed production and distribution systems, the technical research requirements are likely to be different from those of centralized systems. The main concern should be the maintenance of the physiological quality of seed under field conditions.

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2.5 What technical research is needed on the genetic quality of tree seed?

The establishment of appropriate seed sources is the basis for production of quality material. Selection of the most appropriate seed source can significantly increase tree production, since a bad seed source may result in reduced production or even total failure. Documentation on seed sources and how seed is collected from these seed sources is the customer's only guarantee of genetic quality. In some countries, seed zones that delimit the areas within which seed can be distributed exist (species planted outside their seed zone may result in poorly growing trees), but further research on many indigenous species is needed in most countries.

Another area where research is needed is seed source establishment on farmland. Research is needed on how genetic quality can be maintained for such seed sources, in particular, how to avoid inbreeding. Research is needed on pollination of these species, so that trees can be arranged and managed in ways that ensure that they receive pollen from many trees.

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2.6 What research on tree seed systems is needed?

Although a lot of very valuable information has been collected through research at NTSCs, such research was conducted within the context of a centralized tree seed system. The development of decentralized seed production and distribution chains requires a broader understanding of organizational development and agricultural entrepreneurship. The fundamental issues are:

- How to make seed sources profitable
- How to market seed and seedlings
- How to make viable enterprises for production and distribution
- How to maintain quality (both genetic and physiological)
- What inter-institutional links need to be maintained or developed for longer-term implementation.

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2.7 How should I plan and carry out research?

Research aims at overcoming problems and improving methods. It is important that research focuses on important problems. Some problems can be solved by using simple tests. In other cases only research institutions and trained researchers can do the more complicated research. Although not every actor in a seed system (see chapter 1) can be expected to conduct the more complicated types of research, actors can play an important role in providing information about serious problems that they encounter. A good research methodology and plan is a prerequisite for obtaining good results.

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Introduction

Research on tree seed and seedling systems in developing countries should be based on the context that agroforestry trees are planted by smallholder farmers to improve their livelihoods and incomes.

As detailed in chapter 5, three types of information are important in well-functioning seed systems: technical information, economic information and information about partners within networks.

The technical aspects of tree seed are relatively simple and can be solved by applying simple methods – such research does not have to be costly and sophisticated. The socio-economic aspects of production, procurement and distribution of tree seed are in most cases relatively straightforward. Within decentralized seed production systems in tropical countries, socio-economic research should focus on improving the capacity of local entrepreneurs to make tree seed and seedling production and distribution a sustainable business and on improving the capacity of farmers to become informed tree seed customers.

Since there are around 50,000 tropical tree species, it can be expected that not everything is known yet about the biology and uses of each species. Moreover, domestication of tropical tree species has only recently been a topic of scientific research. Therefore, further research on the domestication of tropical tree species, and on the performance and ways of improving tree seed systems is required.

Good research focuses on important problems and tries to efficiently solve these problems. Some people, such as biometricians, are specifically trained in helping others to conduct good research. It is always a good idea to discuss research plans with them before embarking on any research activity.

2.1 Why is research on tree seed systems needed?

The generation and distribution of information is almost as important as the collection, production and distribution of tree seed (see chapter 5). Without information, it will not be possible to set up a well-functioning tree seed system.

In short, research is needed on tree seed systems because we do not know everything yet. As a key guideline, research should only be conducted when information is not available, and when it is important to know a certain piece of information. For example, when seed of a particular species has no problem germinating under its present conditions, then it is not relevant to conduct research on germination of that species.

There are two main reasons why we do not know everything yet. The first reason is that a very large number of tropical tree species are used by farmers, and that complete technical information (see below for types of technical information) is only available for some of these species. The second reason is that tree seed systems can be organized in various ways (see chapter 1), but to date research has mainly been conducted in the context of a centralized system through NTSCs. Traditionally NTSCs have had sole responsibility for collecting, procuring and distributing tree seed. In many countries, NTSCs are no longer the only important participants in collecting, procuring and distributing seed and the context of research may be so different for the new participants that the same questions need to be asked again about the same species.

Based on these two reasons, tree seed research can be categorized as species-specific research (technical research focused on a specific tree species) and system-specific research (research that addresses questions about how to organize and support decentralized tree seed collection, procurement and distribution (economic information and networks)).

Since information is needed by a particular actor in a seed system, it is obvious that **research will be useless if the results of the research do not reach the actor who needs them**. The need for the distribution of information together with seed can not be over emphasized (see chapters 3, 4 and 5). It is very important that this information is available to every interested person within the seed system, especially information that is collected by the public sector.

2.2 Who needs to conduct tree seed research?

In many tropical countries, NTSCs have been established with the mandate for collecting, producing and distributing tree seed and for conducting research on tree seed. Many of these NTSCs have actively conducted research into the physiology of seed and seedlings, and the use of appropriate species and provenances. Often, the research was done in partnership with institutions such as the DANIDA Forest Seed Centre (DFSC), the Australian Tree Seed Centre, the International Plant Genetic Resources Institute (IPGRI), the Oxford Forestry Institute (OFI) and the World Agroforestry Centre (ICRAF). Although the NTSCs have done a very good job in conducting species-specific tree seed research, only a limited number of species has been investigated. Moreover, the current wave of privatization of NTSCs may further limit the amount of research conducted. It is likely that NTSCs will primarily conduct research on economically important species, thus leaving out many indigenous species that may be only locally important. [There are notable exceptions, however. The Tanzania NTSC, for example, published a book on the seed germination of indigenous trees (Msanga, 1998)].

For these reasons, other actors in the tree seed sector (for example, NGOs) are encouraged to conduct small-scale research activities **if and when there are particular problems with a particular species**.

As we saw earlier, there are research needs for system-specific questions. The NTSC can also play a role in answering these questions. Ideally, such research should involve other actors, where questions are generated and answered within networks rather than by isolated actors. The research should also respond to questions that arise in the extension system (see chapter 3).

2.3 What technical research is needed?

Seed quality needs to be maintained from the moment the seed is collected to the moment it is provided to the final user. Part II of this Toolkit is devoted to technical issues involved in maintaining seed quality. Much of the information that is provided there was based on research conducted by NTSCs.

So, **when information is not available for a particular species and when this species suffers from quality loss**, research needs to be conducted to maintain seed quality.

Particular aspects that may need research are:

- Seed sources: genetic quality (see chapter 7).
- Seed collection: genetic quality, physiological and physical qualities (see chapter 8).
- Seed processing: physiological and physical qualities (see chapter 9).
- Seed testing: physiological and physical qualities (see chapter 14).
- Seed storage: physiological and physical qualities (see chapter 10).

It is important to determine where a particular problem with a particular species occurs. Documentation and the development of guidelines and procedures for handling of tree seed are therefore very important since these can indicate when and where a particular problem has occurred. The problem could then potentially become a research question if there is no explanation for it in the documentation.

2.4 What technical research is needed on the physiological and physical qualities of tree seed?

Research on the physiological and physical qualities of tree seed has predominantly been carried out within the context of a centralized tree system. In this context, the central institution (often the NTSC) has access to **laboratory facilities** for testing seed, **cold storage facilities** for optimal storage of seed, and **well-trained human capacity** for seed collection and seed handling.

In decentralized seed production and distribution systems, the technical research requirements are likely to be different from those of centralized systems. The main technical research concern should be the maintenance of physiological quality under **field conditions**.

Because most of the past research was conducted within the context of a centralized tree system, much of the technical information that is provided in the second technical part of this Toolkit was also produced within this context. This research assumed that near optimal conditions are available for producing the highest quality seed. It may be that seed of acceptable (not the lowest and not the highest) physiological and physical quality will be the best in many situations.

2.5 What technical research is needed on the genetic quality of tree seed?

The establishment of **appropriate seed sources** is the basis for production of quality material (see chapter 7). Selection of the most appropriate seed source can significantly increase tree production, since a bad seed source may result in reduced production or total failure. Documentation on seed sources and collection from these sources is the only guarantee for genetic quality.

One of the essential requirements for successful plantings is a good knowledge of how to match species and provenances with planting sites. This is a basic requirement for utilizing genetic potential. Most NTSCs have used **seed zones** (see chapter 6) for selection and management of seed sources. The seed zones are ‘common sense’ tools that can be used to construct a system of homogeneous environmental zones (ecologically similar areas), where the general rule is not to move seed from its sources across to different zones. This will reduce the risk of failures caused by planting material that is not well adapted to an area.

A local seed source may, however, not always be the best performer at a given site, because local seed sources may not actually be the best adapted. Especially when economically important traits are taken into consideration, non-local seed sources may produce more valuable products. However, finding an alternative, non-local, better seed source requires substantial resources such as wide-range seed collection, establishment of (maybe repeated) trials in the specific environments, evaluation and analysis, and time. The long-term performance of local seed sources is known, therefore, non-local seed sources should in general only be used as an alternative to viable local seed sources if the choice is based on solid testing.

Farmland and natural forests are two distinct areas where research is needed on seed source establishment. NTSCs have traditionally based definitions of quality for seed sources on rules that have been developed for plantation species in temperate areas. These rules are not really useful for trees that grow outside plantation blocks.

Because of deforestation, the majority of trees of promising indigenous species can now only be found in degraded natural forest or on farmland. The future seed sources for many species (both indigenous and exotic) that are now introduced to farmers will be from trees that grow on farmland. Research on how genetic quality can be maintained for such seed sources, in particular on how to avoid inbreeding, is needed. Research on the pollination of these species is therefore needed so that trees can be arranged and managed in ways that ensure continued pollen exchange from many trees. Research on bulking of seed from different mother trees, so that it has suitable levels of genetic diversity should also be conducted.

2.6 What research on tree seed systems is needed?

As detailed above, most research in the past has been conducted through NTSCs. Although a lot of very valuable information has been collected so far, NTSCs based this research on a centralized tree seed system. Therefore, this research has mainly focused on raising awareness of the importance of tree planting, and marketing of tree seed from a central location.

The development of decentralized seed production and distribution chains requires a broader understanding of organizational development and agricultural entrepreneurship. The fundamental questions are:

- How do we make seed sources profitable? Depends on the type of tree species and the development of networks for the sale of seed and seedlings.
- How do we market seed and seedlings? Includes how information is made available and how production chains are arranged.
- How do we make viable enterprises for production and distribution? Address training requirements and appropriate networks.
- How do we capture farmers' innovations and adaptations of technology? This issue needs to be validated by formal research.
- How do we maintain quality (both genetic and physiological)? Quality standards are determined in this context.
- What inter-institutional links need to be maintained or developed for longer-term implementation? The relationship between public and private sector initiatives needs to be addressed.

Social research on tree seed systems therefore needs to address several issues that are significant to the production and marketing of smallholder farm products. Of particular relevance is the question of how participants' business skills can be improved. Part III of this Toolkit is devoted to this topic for this reason.

Currently, there are no blueprints on how a decentralized system should be organized, although some insights can be obtained from crop seed systems (see chapter 1). This is particularly so when the objective of the tree seed system is also to reach poor farmers, and to provide seed suitable for a range of agro-ecological environments.

2.7 How should I plan and carry out research?

Good research focuses on important problems and uses an efficient way of obtaining solutions to these problems. Good research focuses on what is important to know, not just on what would be nice to know. Good research also uses cost-effective methods to obtain useful results. Before you start conducting research, it is important to find out whether somebody else has already investigated the same or similar problems, so that you can avoid investigating something that is known already (re-inventing the wheel).

Experts, such as biometricians, are specifically trained in helping others to conduct good research. It is always a good idea to discuss research plans with them before embarking on any research activity. Involving biometricians at a later stage in the research (for example, when the results are analysed) is very risky since the method of data collection may not suitably address the specific research question.

In this chapter, we have discussed some of the major problems in tree seed systems. Effective research depends on good technical skills (biological knowledge and social understanding), good people skills (management and extension) and good administration of inputs (information and money).


Some of the problems can be overcome by using simple applied research, while in other cases, only research institutions and trained researchers can do the more complicated controlled tests and interpret results. Although not every actor in a seed system (see chapter 1) can be expected to conduct more complicated types of research, actors play an important role in providing information about important problems to researchers. For example, a CBO can inform a research institute about problems with the germination of a particular species. It is therefore crucial that information flows from researchers to users of information and *vice versa*.

A good research methodology and plan is a prerequisite for obtaining good results. There are many guidelines for planning and carrying out research. An example of a research protocol that specifically targets tree seed is the desiccation protocol for handling and storage of seed of high-value indigenous tropical tree species (DFSC and IPGRI, 2000). An example of a general checklist for preparing protocols for experiments with farmers has been prepared by ICRAF (Coe, 1999). A thorough discussion of research methods is beyond the scope of this Toolkit. The most important thing is to contact specialized people such as biometricians before starting any larger-scale experiments. It is also essential to know clearly what problem is being investigated and how the results may be useful.

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Chapter 3:

Extension

Summary

3.1 What is extension?

Extension has been described as a non-formal education that aims at reaching people in their own context and life situations. Through extension services, people identify and assess their own problems and needs; they are enabled to cope with them and they are also inspired to take certain actions. To ensure success and sustainability of extension programmes and any development venture, active participation of the beneficiaries is important.

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3.2 How have the extension approaches and methods evolved over the last four decades?

Extension theory and practice have evolved over the past four decades from transfer of technology in the 1960s and the 1970s, through farming systems approaches in the 1970s, and participatory technology development in the 1980s, to facilitating participatory social learning in the 1990s and the 2000s.

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3.3 What are the main sources of extension services?

- Conventional public extension services (governments and NGOs).
- Farmer-led extension initiatives.
- Private extension services.
- Extension through nursery operators and seed dealers.
- Extension through CBOs.

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3.4 What is the role of extension services in the diffusion of information and technologies?

Extension services assist people in identifying and assessing problems and needs that affect them. Extension services help people to access knowledge and skills. They also inspire people to solve their problems and meet their own needs.

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3.5 Why should farmers be involved in the provision of extension services?

To ensure that whatever interventions in extension and development are relevant to the targeted communities, farmers' knowledge, skills and innovations should be tapped, developed further and incorporated into extension messages. Farmers need to be empowered to be competent in sharing information and in developing practical solutions. Active involvement of farmers is also useful in complementing the efforts of the main extension providers and in decentralizing the provision of extension services. Thus, farmers' involvement makes extension more effective, responsive and accountable. Nursery operators and seed dealers often make excellent farmer extensionists. They help to simplify complex technical information through the use of local language and adapt and facilitate the two-way flow of communication to fit the local situation.

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3.6 What are the key issues in the scaling-up process?

The scaling-up process includes: building strategic partnerships, mobilizing the required resources, strengthening the technical capacity of local institutions, sharing information, emphasizing farmer-centred research and extension, availing technical intervention options, inputs and market access and developing enabling policies.

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3.7 What extension approaches are used to scale up agroforestry practices?

- Training and visits (T&V) extension approach.
- The farming systems approach (FSA).
- The contact group approach.
- Farmer field schools (FFS).
- The Landcare Programme.
- Campesino a Campesino (Farmer to Farmer) in Central America.
- The 'Mirror technique' in extension: Experiences from Kenya Wood Fuel Agroforestry Programme (KWAP).

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3.8 Which extension methods and tools are used to scale up agroforestry practices?

- Demonstrations.
- Field days.
- Farmer tours.
- Exchange visits.
- Farm visits.
- Official meetings at community level.

- Meetings.
- Observations.
- Discussions.
- Training.
- Agricultural shows.
- Learning resource centres (LRCs).

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3.9 What factors limit the delivery of extension services?

Diminishing resource allocation, use of inappropriate extension methods and low extension staff coverage have caused a decline in the delivery of extension services over the years. The declining extension coverage has led to an increase in demand for food. Innovative extension approaches that incorporate the principles and practices of participatory extension are therefore a must.

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3.10 What are participatory approaches and how can they be implemented?

Participatory approaches involve building partnerships and alliances between the extension providers and the recipient community. The role of each stakeholder is recognized and articulated at all stages of project implementation. Participatory approaches also involve capacity building at grassroots levels and entrepreneurial skills development. Such approaches encourage communities to effectively harness local resources and their own capabilities. A close working relationship between various stakeholders is therefore necessary.

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3.11 Whom do you target in participatory extension approaches?

- Grassroots level communities.
- Special focus groups such as youth, women groups, or people living with and affected by HIV/AIDS.
- Entrepreneurs at all levels, from grassroots to national.
- Individuals with special technical needs such as group leaders and committee members.

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3.12 What general problems are common in extension systems?

Agricultural and forestry extension services are complex and have a wide scope, making it difficult to measure their impact. Extension services generally lack accountability to their clients (farmers) and also lack reward systems. They suffer from political interference, insufficient funding and links to information sources and markets.

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Introduction

Extension plays an important role in the adoption of new farming innovations and practices all over the world. Extension service providers range from governments, NGOs and the private sector to non-conventional providers such as farmer organizations and individual entrepreneurs. Different extension approaches and methods have been tried in different parts of the world with varying levels of success. The participation of the beneficiaries in designing, implementing and monitoring extension activities is critical to the success of any extension initiatives.

3.1 What is extension?

Extension is a non-formal education that aims at reaching people in their own context and life situations. Through the help of extension services, people identify and assess their own problems and needs; they are enabled to cope with them and they are also inspired to take appropriate action. However, the low performance of public extension services hinders the realization of these benefits. Active participation of the beneficiaries is necessary for the success and sustainability of extension programmes and development ventures.

3.2 How have extension approaches and methods evolved over the last four decades?

Extension theory and practice have evolved over the past four decades from transfer of technology in the 1960s and the 1970s, through farming systems approaches in the 1970s, and participatory technology development in the 1980s, to facilitating participatory social learning in the 1990s and 2000s.

3.3 What are the main sources of extension services?

3.3.1 Conventional public extension services

Mainly provided by governments and NGOs as part of a public good, conventional public extension services aim to increase or sustain production of food and other essential commodities.

3.3.2 Private extension providers

Private extension providers promote selected commodities that generate good profits and are usually provided on demand by producer organizations. They meet specific market needs. However, smallholder farmers may not be able to afford their services. In Kenya, private extension is successful in the provision of services to the veterinary and horticulture sectors.

3.3.3 Extension through CBOs

Members of farmer groups, associations and cooperatives disseminate information and planting materials to other farmers. A good example is the Dairy Goat Association of Kenya (DGAK), an umbrella group that promotes the keeping of dairy goats and related aspects such as goat feeding, breeding and health care in the East African region.

3.3.4 Farmer-led extension initiatives

This method of extension depends on ‘farmer-extensionists’ and good support from the main extension providers. In agroforestry, farmer-extensionists include nursery operators and seed dealers (see chapter 19).

Individuals or farmer groups take the initiative of selling seed and seedlings. This involves aggressive promotion and marketing campaigns. The seed dealers and nursery operators are usually well linked to extension and research services; therefore, they get information on seed and seedlings that are in demand in a given area. Successful farmer-to-farmer extension has been witnessed in different parts of the world (see chapter 19).

3.4 What is the role of extension services in the diffusion of information and technologies?

- Extension services assist people to identify and assess their own problems and needs.
- Extension helps people to access the required knowledge and skills to cope with problems and needs. It also inspires people to solve their problems and meet their needs.
- Extension services are a necessary ingredient of agricultural development because they improve the quality of agricultural labour by educating farmers. This education leads to increased productivity and marketing.
- Extension services facilitate the diffusion of improved farming practices among the farmers and ultimately improve livelihoods over a wide area.

3.5 Why should farmers be involved in the provision of extension services?

- The involvement of farmers in extension ensures that their knowledge, skills and innovations are tapped, developed further and incorporated into extension messages that are relevant to the local situation.
- Information sharing among farmers decentralizes the provision of extension services. Farmers come up with practical solutions that address the local situation regarding the environment, social and economic issues.
- Farmer-extensionists use the local language to simplify complex technical information, and adapt the messages to fit the local situation.

- Farmers are empowered to solve their own problems without outside intervention.
- Farmers' involvement makes extension more effective, responsive and accountable to the clients (farmers) and less costly to governments.
- Farmer-extensionists complement the efforts of the main extension providers, especially where there is low coverage by main extension staff.
- Improved interaction between farmers and extension agents is likely to lead to the development of better communication channels for local communities.

3.6 What are the key issues in the scaling-up process?

Scaling-up involves expansion and replication of practices and innovations to reach out to more people in a wider geographical area. Scaling-up increases the level of impact. The key factors for scaling-up include:

- Building strategic partnerships and alliances.
- The presence of appropriate and enabling policies.
- Mobilizing the required resources.
- Building the technical capacity of local institutions.
- Facilitating the sharing of information, knowledge and skills.
- Putting emphasis on farmer-centred research and extension approaches.
- Providing a wide range of technological options for farmers to choose from.
- Availing the necessary inputs, such as improved germplasm and at places that farmers can access and at prices that they can afford.
- Building on lessons from past successes and failures, rather than reinventing the wheel.
- Making information available on market options and access.

3.7 What extension approaches are used to scale up agricultural practices?

Donor agencies such as the World Bank, Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD) have funded the implementation of several extension approaches, mainly through government extension services. Some of these approaches include:

3.7.1 Training and visits (T&V) extension approach

This approach was sponsored by the World Bank and implemented by public extension systems managed by governments. It involves frequent farm visits by extension staff who give advice and train selected farmers (contact farmers). The farmers in turn train other farmers in their neighbourhoods (follower

farmers). The T&V extension approach is quite successful (particularly in South East Asia) in the context of single commodity irrigation schemes, where timeliness of operations is necessary for cropping success. In Africa however, partly due to the diverse nature of the farming systems, the multiple enterprises on farms, and the complexity of farmers' risk-averse decision making, the single message extension content of this approach is less successful. T&V critics also argue that this extension approach targets 'the wrong contact farmers' and concentrates resources on a few individuals (contact farmers).

3.7.2 The farming systems approach (FSA)

FSA emphasizes a holistic approach whereby research or extension staff jointly focus on all problems and issues related to farming activities in an area. This calls for the multidisciplinary participation of various stakeholders. FSA requires complex logistical arrangements to mobilize available resources and to ensure the participation of different stakeholders.

3.7.3 The contact group approach

The focus in this approach is common interest groups (CIGs) that are involved in addressing a particular issue that affects the group members. This approach assists the implementers in reaching many people using less resources and time; for instance when undertaking farmer training and meetings to evaluate the potential impact of a given technology. The CIGs approach has the advantage of efficient use of scarce resources and time. It provides the opportunity for farmers to exchange information through farmer-to-farmer extension methods, leading to a high multiplier effect on technology diffusion and adoption.

3.7.4 Farmer field schools (FFS)

The FFS is comparable to a classroom without walls; farmers meet under a tree or in other convenient places to discuss their problems and to develop solutions for these problems. FFS emphasize learning through experience. The farmers, with the help of extension or research facilitators, identify issues that they can solve on their own, and issues that require external assistance. Discussion topics are guided by seasonal cropping or livestock rearing calendars. Farmers gain and accumulate knowledge and skills through experience and hands-on activities. The FFS has been quite successful in integrated pest management (IPM) programmes in Asia and Africa.

3.7.5 The Landcare Programme in Australia

This initiative was started in Australia in the mid 1980s as a land protection programme based on community participation and holistic land management principles. The programme was mainly implemented through Landcare groups. The groups were formed by volunteers who wanted to improve the long-term health of the land. Landcare provides training to the facilitators and coordinators. High profile and committed political leadership supports

the grassroots communities to ensure the success of programmes. Farmer-prioritized research expenditure is one of the core elements of the Landcare approach. The programme is also being implemented in the Philippines, South Africa and Uganda.

3.7.6 Campesino a Campesino (Farmer to Farmer) in Central America

This type of farmer-to-farmer extension approach is widespread in Central America. The approach was first developed in Nicaragua as a solution to the top-down transfer of technologies. It is now widely practised by poor farmers in Nicaragua and Mexico. The approach promotes the culture of inquiry, innovation, experimentation and knowledge-sharing among small-holder farmers, since it involves farmer promoter-teams. Farmers exchange experiences through traditional communication methods such as drama, poetry, music, exchange visits and participatory rural appraisals (PRAs). The movement has influenced NGOs to adopt some of its methodologies, thereby shaping the approaches of many NGOs in that region.

3.7.7 The Mirror Technique in extension: Experiences from KWAP

The Kenya Woodfuel and Agroforestry Programme (KWAP) championed this method. KWAP, a development organization that operated in western Kenya in the 1980s and 1990s, involved farmers in providing extension services using traditional communication systems. It used drama, role play, proverbs, poems, traditional songs and dances that ‘mirrored’ back the problems facing the community. KWAP helped to create mass awareness on issues such as farming, environmental conservation and community health (for example, HIV/AIDS and other communicable diseases). The method encouraged discussions at household and society levels. It made people open up and discuss sensitive issues that are often surrounded by myths, taboos and social norms that hinder the adoption of sound practices and innovations. This technique was successful in overcoming the cultural barriers that hindered women from planting trees within some western Kenya communities.

KWAP had a strong component of monitoring the impact of projects. The Mirror Technique was used in farmer meetings, field days, agricultural shows, public rallies and farmer meetings (defined in the section below). The technique both entertains and educates people at the same time.

3.8 Which extension methods and tools are used to scale up agroforestry practices?

Extension methods have a lot of similarities since all involve interactions between farmers and resource persons (extension workers, researchers and

farmer-extensionists). The following methods can be applied in any of the extension approaches described above.

3.8.1 Demonstrations

A form of training by displaying how a technique works at an institutional farm, on public land or in a farmer's field. During a demonstration session, farmers are encouraged to try out certain skills on their own but must follow a given set of guidelines, for example, practising grafting fruit trees or sowing seeds in a nursery bed.

3.8.2 Field days

Farmers meet resource persons such as innovative farmers, extension workers or researchers to discuss important topics. Field days often involve discussions, displays and demonstrations on a set of technologies in the farmer's field, research or extension demonstration plots. In most cases field days involve many participants and resource persons. They are also used to promote the use of certain products and practices.

3.8.3 Farmer tours

These are planned visits by a group of farmers to one or more farms where the farming practice or technique being promoted is working well. Farmers and resource persons engage in discussions, observations and interactions. Farmer tours are a very effective extension tool. The visits could be to nearby sites or even in different countries.

3.8.4 Exchange visits

Farmers from one village visit farmers from another village, and later on the visiting is exchanged. These visits can also take place across international borders. Often, information, skills and planting materials are exchanged between the hosts and the visitors. Several exchange visits have been conducted between Kenyan, Tanzanian and Ugandan farmers and extension staff.

3.8.5 Farm visits

These are organized routine visits to see the farms where researchers, extension and development workers are undertaking activities with the farmers. The main purpose of the visit is usually to monitor and evaluate the performance of farming technologies or practices being promoted. Discussions and observations are used in this process. The alternative to this method would be the distribution of audio-visual materials such as leaflets, video tapes or listening to radio and watching television programmes with specific messages.

3.8.6 Official meetings at community level

These are meetings for the community organized by government administrators. They usually involve different government departments and organizations that operate in an area.

3.8.7 Meetings

These can be formal or informal and can be targeted to specific issues or can be more open. One person is appointed to coordinate and moderate the discussions. Meetings are held to discuss upcoming plans, to resolve issues or to monitor progress and identify group or community needs. In some cases, the proceedings of such meetings are recorded.

3.8.8 Observations

Dissemination methods such as farmer visits, tours and demonstrations help farmers observe how certain practices are carried out, and to easily replicate them on their own farms. Observation is used together with other tools.

3.8.9 Discussions

This is the most common vehicle through which information is shared because it is the most flexible and responsive way to handle a variety of information needs. Field staff use discussions to gather information from farmers and to provide answers to questions from the farmers. It is through discussions that farmers share information among themselves and with external agencies.

3.8.10 Training

This is a general term that covers all aspects of passing knowledge and information to farmers or staff. It may involve other dissemination methods already discussed, such as demonstrations, tours and field days.

3.8.11 Agricultural shows

These are fairs organized to create awareness and promote certain practices and products. They usually involve display and sales of agricultural produce. The shows are characterized by official speeches, entertainment and learning. In Kenya they are undertaken annually at regional level.

3.8.12 Learning resource centres (LRCs)

LRCs are set up close to the learners and are equipped with reading and demonstration materials that the learners can easily access. The LRCs can be in a farmers' training centre (FTC), a school, a building or section of a building set aside by the community. LRCs that have access to an electricity grid or solar power can be equipped with radio cassettes, videos, DVDs, and internet connection. The use of information and communication technologies (ICTs) in learning centres can greatly enhance the interactivity of the learning experience and familiarize the learners with a variety of multimedia.

3.9 What factors limit the delivery of extension services?

Delivery of extension services has been declining over the years due to:

- Diminishing resources from governments and donor communities.
- Use of inappropriate extension approaches and methods that are not well adapted to meeting the changing needs of farming communities.
- Decreasing extension coverage as a result of the increasing population in relation to the decreasing number of extension staff resulting from re-trenchment and low staff recruitment.

The paradox is that low extension coverage results in increased demand for food, which in turn calls for improved and innovative extension approaches.

3.10 What are participatory approaches and how can they be implemented?

Participatory approaches involve the development of partnerships and alliances between extension providers and recipient communities. The role of each stakeholder is recognized and articulated at all stages of project implementation. Many development agencies prefer participatory approaches in research and extension but most practitioners find the approaches difficult to implement. Participatory approaches lead to the enhancement of the community's social welfare and economic empowerment.

The main components of participatory approaches are: capacity building at grassroots levels, entry through focus groups, and entrepreneurial development.

Capacity building at grassroots levels should empower local communities to identify and analyse their problems, develop ways and means to overcome these problems, and meet their needs using local resources.

Specific interventions can initially be tested with focus groups before disseminating them on a wider scale. Focus groups also help in overcoming obstacles that hinder development by demonstrating the successes of a given set of interventions.

Extension agents should strive to develop an entrepreneurial culture through:

- Identifying marketable products, developing the uniqueness of a product and continuously refining that product.

- Finding innovative ways of utilizing local raw materials to produce appealing new products or concepts.
- Developing effective marketing strategies capable of carving out a market niche for the new products or concepts.
- Advocating the development and implementation of policies that protect local producers. These may include levies on imports and patenting of local innovations and products.

Participatory approaches can be implemented in the following ways:

- Sensitizing a community to form its own development vision and work towards a mission of realizing the ideals of perceived change and development.
- Ensuring that the extension agent works hand-in-hand with the beneficiaries at all stages of development.
- Encouraging communities to trust and have confidence in their own opinions and capabilities.
- Promoting the concept of first harnessing local resources in solving problems before looking for external interventions. This encourages communities to be the key determinants of their own development and future.
- Encouraging the use of bottom-up planning processes and developing an entrepreneurial culture.

3.11 Who do you target in participatory extension approaches?

The main categories of potential beneficiaries of extension interventions include:

- Grassroots-level communities.
- Special focus groups such as youth and women's groups, school environmental and agricultural clubs.
- Entrepreneurs at all levels from grassroots to national.
- Individuals with special technical needs such as project committee leaders, retirees and people living with and affected by HIV/AIDS.

3.12 What general problems are common in extension systems?

Extension systems suffer from some of the following problems:

- Agricultural and forestry extension are complex and wide in scope, making it difficult to delineate the extent of issues covered by extension staff.
- It may be difficult to measure the impact derived solely from extension services since some of the impact results from other interventions.
- Lack of political support to extension services and the exposure of extension staff to political interference may lead to low morale.

- Lack of accountability of extension agencies to farmers.
- Lack of structures and mechanisms that recognize, reward and benefit good performers as well as penalizing and reprimanding bad performers.
- Insufficient resources to enable long-term planning and impact of extension services.
- Poor links of extension staff to established sources of new information and technologies such as research centres and universities. Extension staff may also lack essential facilities such as regularly updated library materials and internet connections.
- Poor links, market knowledge and negotiation skills, and orientation to markets to meet the challenges of liberalized global markets.

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Chapter 4:

Training

Summary

4.1 Why is training on seed systems important?

Seed production and distribution are as old as agriculture and forestry themselves. High-quality seed or other types of germplasm are the prerequisite to obtaining good plant yields. In agriculture and forestry, the introduction of good seed systems is becoming increasingly complicated as a result of artificial interventions to obtain better seed and germplasm, intellectual property rights, commercialization, distribution across borders, and policies and regulations related to seed production and distribution. Tree seed collection, production and distribution have become more and more commercialized in many countries. Training to improve the knowledge and skills of all the actors in seed systems is therefore necessary. In agroforestry, however, especially as far as certain low-value species are concerned, there is less interest in rigorous commercial seed production and it is often the farmers, communities or NGOs who are dealing with this process. It is therefore even more important to train those involved so that they have the right knowledge, skills and attitudes needed to produce good-quality seed and planting materials.

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4.2 How do we determine the need for training on seed systems?

In order to be effective, training on seed systems must be based on needs, opportunities and constraints experienced by the learners. Training needs identification (TNI) is a broad process that studies the overall performance of a system or an institution in order to identify areas for improvement. TNI ascertains that a training need exists and that the particular problem is responsive to training. Training needs assessment (TNA) analyses the causes of a problem, establishes the impact of the problem and clarifies the various situations that must be treated if the problem is to be successfully solved. Good TNA is a demanding process that requires good critical and analytical skills and a systematic delivery. TNA also requires skills in basic communication, interviewing, observing, data collection and recording, data analysis and reporting.

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4.3 How do we organize a short training event on seed systems?

Once the various target groups' needs for training and learning have been identified and assessed, trainers develop clear training aims and objectives. Trainers should develop a specific training curriculum framework that provides the shape, direction and overall approach for the training event. Objectives must be SMART – specific, measurable, attainable or achievable, relevant or realistic and time-bound. For example, a vague objective that reads “Learners will understand seed storage conditions” is not so good as “After visiting a seed storage facility, learners will be able to list and explain conditions that affect seed storage”. Quite often, it will be useful to involve the learners in the identification and development of learning objectives or outcomes. Trainers also need to consider the content, methods and materials for such a course framework, which will facilitate learning and achieving the identified objectives and learning outcomes. When selecting content, it is necessary to keep in mind what knowledge, skills and changes in attitude or behaviour are required and referred to in the learning objectives and outcomes. Knowledgeable and experienced resource persons are of paramount importance for any successful learning event. Good resource persons will make use of a variety of methods and approaches to make sure that learning takes place. Approaches that actively engage the learners, especially adult ones, always work better. Trainers also need to make sure that a training event takes place under optimal conditions, taking into account that the learners will mostly be adults who have certain levels of knowledge and skills, as well as attitudes, which may need to change as a result of the training.

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4.4 What happens after training and learning have taken place?

At the end of a training event, better on-the-job performance should be achieved since learners will have acquired the required knowledge and skills and changed their attitudes and behaviour. Therefore, providing follow-up activities and assessing the impact of training in order to improve its effectiveness are very important.

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Introduction

Building and developing the capacity of the different actors involved in the sourcing, production and distribution of tree seed for farmers aims at imparting knowledge and skills, as well as changing attitudes and behaviour. Merely producing and distributing tree seed to farmers only helps a limited number of communities in the short term. However, teaching farmers how to successfully produce and distribute their own tree seed provides the much-needed long-term sustainability needed to implement agroforestry interventions. Such training has to be based on training needs identification and assessment. This chapter suggests some methods and approaches that can be used to develop learning events. Follow-up after learning has taken place determines whether the training has achieved its intended impact.

4.1 Why is training on seed systems important?

As indicated in chapter 1, there are many different ways and actors involved before tree seed reaches its ultimate destination. At the more organized and often commercial levels, seed systems are operated by people who have the knowledge, skills and attitudes required to produce and distribute high-quality seed and other planting materials. This is mostly the case for high-value agricultural crops and forestry species. However, agroforestry seed production and distribution rarely attract the same level of interest and sophistication. The actors in these seed systems may not always have the necessary training nor attitude, increasing the risk of low-quality seed or planting materials. The overall result is the poor performance of the agroforestry interventions and technologies that the tree species are meant to support. Some people may not know how to source or produce tree seed from agroforestry tree species; they may also have problems harvesting, collecting or storing such seed. The best solution to this lack of knowledge, skills and attitudes is training and extension. Through training and extension, seed system actors will become knowledgeable about breeding, multiplication, harvesting, processing, storage, distribution, marketing and all other aspects of sustainable seed systems.

Local authorities, national governments and international bodies have developed policies, legislation, rules and regulations that aim to protect producers and consumers from unscrupulous seed collectors, producers or distributors. For example, intellectual property rights protect those who have invested in producing better quality seed in terms of production and resistance to pests, diseases and adverse growing conditions such as drought, salinity, temperature extremes and so on. Plant quarantine regulations ensure that pests and diseases are not spread from one country to another thus putting food or tree production at risk. Trading in seed is often subject to strict requirements in terms of storage, packaging and labelling. As a result, even those who are not

directly involved in collection or production may also require some form of training to ensure that their actions do not adversely affect other actors.

It is therefore important to understand the working conditions under which these various actors perform their activities and duties and to identify potential problems that affect their performance. These problems can then be addressed through some form of training or learning in the form of short courses, workshops, seminars, practicals and learning materials development. Only knowledgeable, skilled, experienced and well-trained staff working in seed systems can ensure that the ultimate user of tree seed and other planting materials fully benefits from their work.

Training and extension on seed systems go hand-in-hand since training is an integral part of a good extension strategy. Both extension staff and the beneficiaries of extension services need some form of training or capacity strengthening. A training-of-trainers (TOT) approach can be used to train extension staff on seed systems and also on conducting a needs assessment, developing and implementing training events and monitoring and evaluation of projects. This knowledge will help extension staff to further train other seed systems actors.

4.2 How do we determine the need for training on seed systems?

The process of understanding the conditions under which the various actors in a complex seed system operate, the ways that they undertake their roles and responsibilities, the way they perform their activities and duties, their relationships, the outcomes of their actions, the problems and constraints that they face, and the ways in which these problems and constraints can be addressed through learning, is known as training needs analysis (TNA). There are three main stages of a TNA (see figure 4.1).

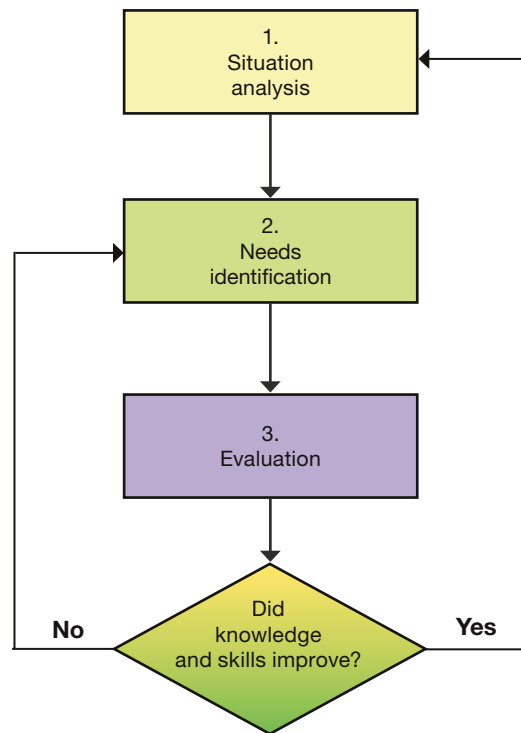
Stage 1: Situation analysis

This is the process of identifying and understanding the current seed system, the key actors, and the political, institutional (social and cultural), ecological and economic circumstances in which they operate. The aim is to gather and document as much relevant information as possible on current activities and trends, future prospects, the roles and relationships between actors, and their expectations, challenges, limitations and opportunities. At this stage, the emphasis is on organizations and other groups, although some individuals may be influential enough to warrant special attention.

Stage 2: Needs identification

This is the process of identifying how the performance of individuals who are undertaking, or are expected to undertake, specific roles and responsi-

Figure 4.1 Training needs assessment (TNA)



bilities may be improved through learning. The aims are to identify specific challenges that can be addressed through training and available options and opportunities for training, and to recommend appropriate roles for organizations that can provide the required training or learning resources.

Stage 3: Evaluation

This is the repeated process of obtaining feedback from the actors and other stakeholders in the system about the training options that have been developed. The aims are to determine if the recommendations made after needs identification are valid; that is, able to alleviate the problems and constraints identified during situation analysis, and whether the options and opportunities that have been proposed or used are appropriate.

4.2.1 What are the key steps in situation analysis for TNA?

Situation analysis is a process of collecting, reviewing and interpreting data and information with the aim of coming up with some conclusions about current circumstances. The following steps mostly refer to situation analysis involving actors of formal seed systems. It is important not to ignore those active in more informal seed systems, even though such systems are less structured and documented.

Step 1: Defining the scope of analysis

It is important to identify the main targets and limits of the study using specified criteria. These criteria may include:

- Geographic criteria: restricting the study to a particular country, or a province, district or agroecological zone in a country.
- Sectoral criteria: restricting the survey to institutions and organizations with formal mandates for forestry, agriculture, marketing or seed production.
- Functional criteria: restricting the study to individuals and organizations with certain roles in seed supply (such as seed owners, procurers or distributors) or other interests (such as extension, management, research, training or education).
- Institutional criteria: restricting the study to either the formal sector (government and NGOs, or commercial nurseries) or informal sector (including farm households and non-commercial nurseries).
- Temporal criteria: stating historical limits for information that will be considered during the analysis.

In addition, the scope of a situation analysis will be influenced by considerations of:

- Duration: the maximum amount of time during which each phase of the TNA should be completed.
- Finance: the amount of funding available to undertake the TNA.
- Human capacity: the availability and capabilities of people to undertake the TNA.

The result of this step will be a statement on the extent (depth and breadth) of the TNA.

Step 2: Describing the context

It is necessary to establish and record the circumstances under which the seed system currently operates. This step involves an examination of previous work and findings relevant to tree seed systems, and within the defined scope of the analysis. The exercise is primarily a desk study that is accomplished through a review of both published and unpublished literature and data sets, which may include project reports, journal articles, government policies, legislation, workshop reports, training manuals, and popular extension materials. Again this step will also need to consider the less formal seed systems that may not be as well-documented or described.

The result of this step will be a document that includes:

- List of key actors and stakeholders.
- Preliminary description of their roles, responsibilities and resources.

- Preliminary description of the relationships among the actors and stakeholders.
- Summary of their documented constraints, opportunities and future challenges.
- List of relevant literature.

Step 3: Stakeholder assessment

The information available from literature and other third-party sources must be verified and additional information collected about the institutions and people who (directly or indirectly) are involved in, affected by, or influence the seed system. This step involves information gathering and discussion, which may be achieved through interviews with key informants, surveys among representative groups of actors, workshops, focused group discussions and other forms of consultation. The approach and methods used should provide information about:

- Key programmes and projects.
- Expectations, objectives and priorities of the organizations.
- The criteria that stakeholders use for ranking of problems and prioritization.
- Perceived successes/strengths and weaknesses.
- Linking among stakeholders.

The results of this step will be a report including the list of key actors and descriptions of their current role and status in the seed system.

Step 4: Synthesis

The final step of the situation analysis is the combination and interpretation of the desk study findings and the stakeholder assessment to identify significant facts and patterns. This step involves review and reflection on these preliminary results that should yield some conclusions and recommendations on the challenges and opportunities within the seed system that is being reviewed.

The result of this step will be an executive summary of the situation, detailing the preliminary conclusions and recommendations for improved performance in the seed system.

4.2.2 What are the key steps in needs identification for a TNA?

TNI is the process of determining ways to increase the competence of people who are undertaking, or are expected to undertake specified management, production, research or development functions. Changes in competence are achieved through learning or reinforcement of knowledge, skills, attitudes and values.

Step 1: Stating expected roles, standards and results

It is important to define the intended levels of activity and results, the tasks needed to achieve these results, the knowledge and skills needed to undertake the specified tasks, and the attitudes and values needed to maintain the desired changes in behaviour. This step involves using knowledge of global or regional measures of quality and procedures for seed supply, as well as knowledge of local priorities, current technology and future trends to develop appropriate descriptions for each actor's function or job.

The result of this step will be a series of descriptive statements on the functions, abilities and relationships among the targeted actors that are expected to achieve stated goals or objectives of the seed system.

Step 2: Determining current standards and the competence gap

In-depth understanding of the current activities, abilities, limitations and other attributes of the targeted actors will facilitate comparison between what is intended and what is actually achieved. This step involves gathering information through observations and direct or indirect interviews, from a representative sample of the identified target groups during the situation analysis. The purpose of the interviews will be to obtain the respondents' opinions about themselves and other actors on their work, their achievements, and shortcomings that may be addressed through further learning.

Depending on the degree of detail of the study, this process may be referred to as task analysis, job analysis or performance analysis. Different methods and techniques have been proposed for these different levels of analysis. Because the performance gap is the sum of gaps in competency and other contextual factors that cannot be resolved through training, it is important for the analysis to distinguish between competence and other factors affecting performance (see box 4.1).

The result of this step will be a written report on the methodology and findings, that concludes with descriptions of the competence gaps of selected actors, the causes of these gaps and desired changes in knowledge, skills and attitudes.

Box 4.1 Factors affecting performance

Performance gap: the difference between the expected level of performance and the actual level of performance, which is the result of gaps in people's competence and other shortcomings in their organizational, social, cultural, political and economic environment.

Gaps in competence: the additional knowledge, skills and attitudes that technicians, managers, agents, farmers and other actors need in order to achieve the expected level of performance.

Step 3: Recommending training and learning activities

The overall purpose of a TNA is to provide justifiable recommendations on learning activities that will bridge perceived gaps in competence. This step involves the identification of appropriate processes and activities for learning that may include any of the following:

- Discussions with people in similar functions or jobs.
- Exchange visits.
- Consultation with more experienced individuals.
- Hands-on training.
- Formal training courses and workshops.
- Field visits.
- Technical reference materials (e.g., toolkits).
- Information (e.g., newsletters).

The result of this step will be a report stating the objectives and target audience for specific training or learning activities, the roles of various organizations in implementation, the anticipated results and outcomes, and criteria that can be used to detect and assess anticipated changes in performance.

4.2.3 What are the key steps in the evaluation of a TNA?

Evaluation is the repeated process of assessing the effectiveness of the training needs, options and opportunities recommended by the TNA. This process requires feedback from all actors and may be conducted at three levels.

1. Prior review of proposed activities and curricula for training.
2. Feedback on the relevance and usefulness of training events in which the actors have participated (that is, immediate reaction to pilot activities).
3. Monitoring of the performance of individuals or groups who have participated in training or learning activities (that is, surveys among supervisors, sponsors, colleagues or clients).

Through evaluation, it is also possible to identify results and outcomes that were not anticipated when the TNA was completed. Some methods of evaluating training activities are described later.

4.3 How do we organize a short training event on seed systems?

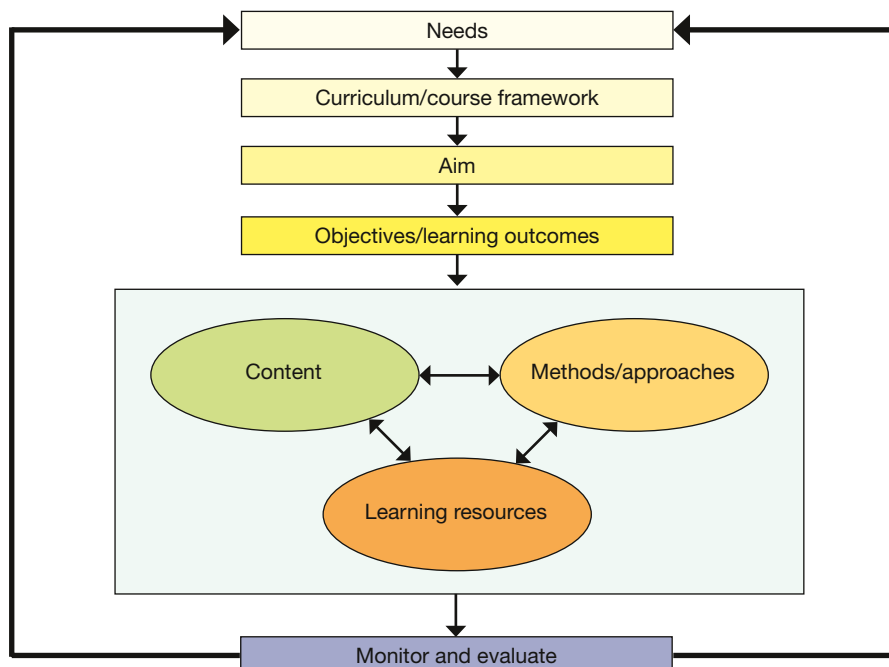
The best way to organize training is to involve the learners in the development of a training event framework that addresses their properly identified, assessed and analysed learning needs. Such a framework provides the shape, direction and overall approach for a training event. Participatory curriculum development is often more effective than that developed by trainers using a top-down approach.

Any training event must have clear aims and objectives that specify what the learner will be able to do as a result of learning. Once the learning framework has been developed, it is important to consider the related content, methods and materials needed to facilitate learning, and to achieve the identified objectives or learning outcomes. The choice and use of content, methods and materials depends on the learning framework. Any training event must also be monitored and evaluated to find out if learning has taken place and how future training events may be improved. Figure 4.2 illustrates the various steps involved in the design of a training event and these are explained in more detail in the following paragraphs.

4.3.1 Aims

An aim is a general statement that gives both shape and direction to a set of more detailed intentions for the future. Aims are not so specific as objectives. They are usually written in terms of what the trainer will do, rather than what the learners will do (outcomes or objectives) by the end of the course. Aims are sometimes broken down into long-term, medium-term and short-term aims. A broad training aim related to tree seed for farmers could be, “To develop the necessary knowledge, skills and attitudes of extension agents so that they can plan, organize and implement tree seed production and distribution systems that will allow farmers in a specific region to successfully practice a recommended agroforestry intervention.”

Figure 4.2 Steps followed in the design of a training event



4.3.2 Objectives/learning outcomes

Aims ultimately give rise to more specific statements – these are the objectives or learning outcomes. An objective is a statement of what learners should be like, or should be able to do after successfully completing a given course of instruction or being exposed to a learning experience. There should be a measurable change in behaviour, hence a ‘behavioural’ verb in the objective. A shopping list of verbs that can be used to develop objectives is given in box 4.2. General verbs such as know, understand, believe, and appreciate should be avoided since these are difficult to interpret when assessing the outcome of learning. For example, an objective that reads, “Learners will understand seed storage conditions” is not so good as “After visiting a seed storage facility, learners will be able to list and explain conditions that affect seed storage”. As we can see from this example, it is also important to give an indication of the conditions (after visiting a seed storage facility) or restrictions under which the learners will operate and also a criterion or performance standard that can be used to determine if learning has taken place to an acceptable standard (number of conditions that affect seed storage). Learning objectives must be SMART – specific, measurable, attainable or achievable, relevant or realistic and time-bound. Quite often, it is useful to involve the learners in the identification and development of learning objectives or outcomes.

4.3.3 Content

Once the learning framework has been developed and the overall aims, objectives and outcomes have been specified, you will need to identify the relevant content, methods and materials needed for the desired changes in the knowledge, skills and attitudes of the learners. Like all other steps in the instructional design process, this is a participatory process between both the learners and trainers. The roles of the trainers and learners should be made clear as early as possible and learning must be seen as a participatory process where the role of a teacher or trainer is facilitation rather than indoctrination.

Content can often be divided into three categories: must know, should know and nice to know. The focus for content development must be on the first and, depending on the available time, content related to the other two categories can be included.

It is also important to properly sequence content. Move from the known to the unknown and from the simple to the complex. Use an existing logical organization of the content (time, topic, job, task, or learning styles) or cover the content in the order of job performance.

Box 4.2 List of verbs useful in writing behavioural objectives

SAMPLE TASKS

Attend	Differentiate	Label
Choose	Discriminate	List
Collect	Distinguish	Mark
Complete	Distribute	Match
Copy	Duplicate	Name
Count	Find	Note
Define	Identify	Omit
Describe	Imitate	Order
Designate	Indicate	Place
Detect	Isolate	Point

STUDY SKILLS

Arrange	Find	Reproduce
Attempt	Follow	Return
Categorize	Formulate	Search
Chart	Gather	Signify
Cite	Itemize	Sort
Circle	Locate	Suggest
Classify	Map	Support
Compile	Organize	Underline
Consider	Quote	Volunteer
Draw	Record	
Document	Relate	

ANALYSIS SKILLS

Analyse	Defend	Plan
Appraise	Evaluate	Present
Combine	Explain	Save
Compare	Formulate	Shorten
Conclude	Generate	Structure
Contrast	Induce	Switch
Criticize	Infer	
Deduce	Paraphrase	

SYNTHESIS SKILLS

Alter	Predict	Rephrase
Change	Propose	Restate
Design	Question	Restructure
Develop	Rearrange	Retell
Discover	Recombine	Rewrite
Expand	Reconstruct	Signify
Extend	Regroup	Simplify
Generalize	Rename	Synthesize
Modify	Reorder	Systemize
Paraphrase	Reorganize	

Box 4.2 (continued)

GENERAL APPLICATIONS

Abbreviate	Extrapolate	Reconstruct
Accent	Graft	Reduce
Add	Group	Remove
Alphabetize	Grow	Replace
Apply	Hypothesize	Report
Argue	Increase	Research
Articulate	Indent	Reset
Bisect	Insert	Revise
Calculate	Integrate	Set
Calibrate	Interpolate	Simulate
Capitalize	Investigate	Solve
Check	Justify	Speak
Compare	Limit	Specify
Compile	Manipulate	Spell
Compound	Measure	Square
Compute	Modify	State
Connect	Multiply	Straighten
Construct	Number	Subtract
Convert	Nurture	Summarize
Coordinate	Observe	Support
Count	Operate	Survey
Credit	Outline	Syllabize
Decrease	Plant	Tabulate
Defend	Plot	Tally
Demonstrate	Prepare	Time
Derive	Print	Transfer
Differentiate	Pronounce	Translate
Dissect	Prove	Type
Divide	Punctuate	Verbalize
Dramatize	Quote	Verify
Edit	Rank	Weigh
Estimate	Read	Write
Extract	Recite	

4.3.4 Method/approaches

When selecting methods for teaching or learning, it is important to consider these four main steps:

1. List all the possible methods which could be used to allow achievement of the objectives.
2. Narrow down this list to ensure the content is adequately covered.
3. Further reduce the list by considering the needs, and capabilities of the learners.

4. Look at the available resources needed in order to select certain methods so as to come up with the final list of methods to teach or learn. Figure 4.3 shows that experience-based learning methods are usually better for achieving training objectives than other learning methods, although they take more time. Figure 4.4 gives an example of experience-based learning.

Quite often, training resource persons choose to teach by lecturing or making a presentation supported by slides. Since most learners learn by doing or seeing, passive participation in a lecture or presentation is often the worst method

Figure 4.3 Learning methods

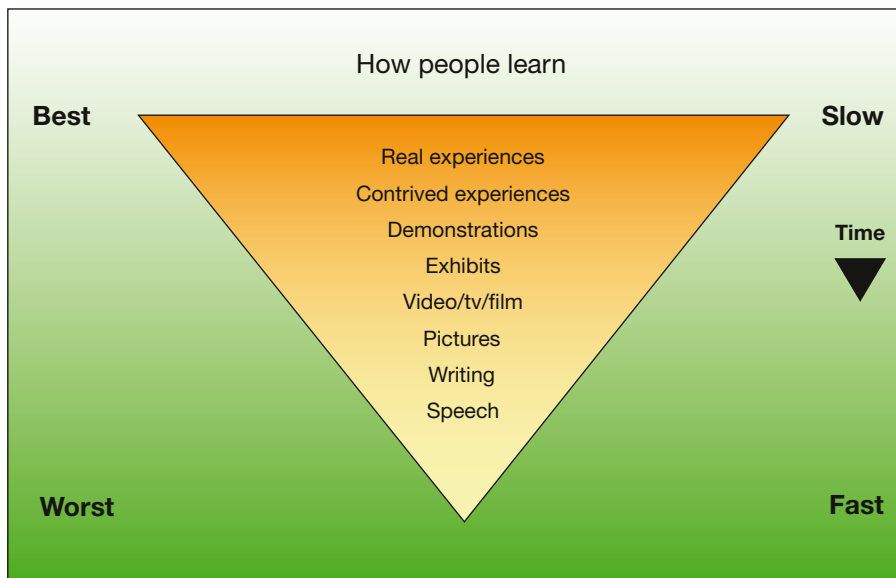


Figure 4.4 Learning by doing



Learning by doing remains the most appropriate way to acquire new knowledge and skills; in this case, grafting trees is illustrated.

one can select to teach and it is important to consider alternatives or additional methods, especially when it comes to learning related to the practical aspects of seed and germplasm production, storage and distribution systems.

Some of these other methods are:

- Group discussions or group work.
- Brainstorming sessions.
- Demonstrations.
- Reading.
- Exercises and problem solving.
- Case study analysis.
- Role play or simulations.
- Games.
- Practicals.
- Project work or research.
- Field visits.
- Attachment or on-the-job training.
- Videos or CD-ROMs.

It is important to try out different approaches and learn from experience what works best with your learners and which approach best contributes to the achievement of the learning outcomes. Approaches that actively engage the learners, especially adult ones, always work better. Always seek feedback from your learners and involve them in testing out teaching or learning approaches. This may give you a better idea how they learn and thus optimize your training methods. Do not mix too many methods when teaching a single subject or topic, as this may become confusing. Teaching methods should enable learning to take place, not simply to prove that a teacher or trainer is a good performer.

4.3.5 Learning resources

Once the content and teaching or learning approaches have been identified, we need to consider which learning resources can be used in support of the subject(s). Learning resources too must address the proposed learning objectives or outcomes as well as reflect the content and methods used. The first step is to identify if relevant learning resources exist. If so, they will probably need to be evaluated and adapted to suit your specific purpose and environment. If they do not exist, you will need to prepare new ones. This can be a time-consuming activity involving several people.

This Toolkit has been developed as the main learning resource for training on the subject of seed systems. It is up to trainers to decide how to best use this Toolkit and the accompanying CD-ROM to support their training activities.

It is not unusual for training to fail to achieve its objectives or outcomes due to issues and problems unrelated to aims, objectives, methods, content or learning resources. Aspects of adult learning need to be taken into account together with practical and logistic considerations that will make the learners feel that they are well looked after and that there is genuine concern on behalf of the trainers that learning will take place. Even though extremely important, the logistic and practical aspects related to the planning, organization and implementation of any training event on the subject of tree seed for farmers go beyond the scope of this specific Toolkit. Training professionals are normally familiar with whatever it takes to properly organize and implement a training event, but often training is an additional responsibility of a person within an organization who is poorly trained, experienced and skilled in the area of learning and instruction. In this case, it is important that such a person is properly prepared to conduct training and learning under optimal conditions. This Toolkit should be of great help to such a person.

4.4 What happens after training and learning have taken place?

The main outcome of training is that the newly acquired knowledge, skills and attitudes are applied in the context of the day-to-day work of the learners. This can only be achieved if the needs of the learners have been properly identified and assessed and if the learning is designed to address these needs. All too often, training is seen as a bonus or benefit for an employee and if there is no strong justification that the training will eventually benefit learners or their employer, human and financial resources will be wasted.

A properly conducted TNA will identify what problems exist within an organization and will distinguish between what can be solved through training and what requires other solutions or interventions. For example, it serves little purpose to train a person on seed storage requiring sophisticated and expensive equipment if the equipment will not be available to the learner after the training.

During and after a training event, monitoring and evaluation (M&E) will indicate if learning has taken place. There are several participatory methods and tools that can be used for M&E. During the training, M&E should focus on addressing immediate problems that arise during the event. Post-event evaluation should target the improvement of future, similar training events.

Once the training event has taken place, it is important to assess its impact. Quite often, this training-related aspect is neglected due to lack of resources or the fact that the training was a single occurrence not related to a broader capacity building or strengthening strategy. Evaluation and impact assessment will be even more important if new training events on the same subject are organized, or if the learner participates in a broader training programme covering related subjects as well.

To assess the impact of training, trainers should ask for feedback from learners on how they are using their newly acquired knowledge, skills and attitudes, using a simple questionnaire. One useful approach is to have the learners develop a personal action plan during the course and use this as a reference to obtain feedback on whether they are implementing the new knowledge or not. During the course, organizers should ask participants how they intend to apply what they have learned in the context of their daily work, without new or additional resources at their disposal. Trainers can use a template form with the learner's name, employer, contact address; a brief description of what the learner intends to develop into practice; name of the possible collaborators; a time frame; and a source of verification that the intended action has really taken place. Depending on the time frame given to implement the plan, training organizers can follow up with an appropriate interview or questionnaire. The focus should be on improving future training and learning. If funds are available, a personal action plan organized on a competitive basis and involving all learners at a training event can be subsidized through a small grant project. Care should be taken to ensure the sustainability of the activities that are to be funded.

In addition to describing how far they have progressed with their personal action plans, the former trainees can be asked to participate in a tracer survey. Tracer surveys are usually conducted through questionnaires or discussions at least one year after a training event to find out:

- How relevant the objectives and contents of the training are to the participants' current roles and work.
- How often they use the skills and knowledge acquired during the training.
- Ways in which they practise and strengthen the skills and knowledge that they have acquired during the training.

Through the tracer survey, training organizers can find out if the training was useful and how they can improve future events. Trainers learn about:

- Participants who have applied the skills and knowledge acquired during the training activity to improve seed supply work.
- Specific ways in which the knowledge and skills acquired during the activity have been used.
- Trainees who have been motivated by the course or workshop to strengthen their competence through further training and exchange visits.
- Specific aspects of the training that the participants felt were most useful.

The questionnaires designed for tracer surveys should be brief as shown in box 4.3. It is advisable to use a mixture of open-ended and closed-ended questions. The questionnaire can also include lists from which participants can select a number of options; for example, when describing ways in which they have used the knowledge gained during the training.

Box 4.3 Sample questions for a tracer survey questionnaire

Has your work in seed supply changed since you participated in the training? (select one)

- Yes
- No

How relevant are the topics covered during the training to your current work? (select one)

- Very relevant
- Relevant
- Irrelevant

How often do you get an opportunity to use the skills you acquired during the training? (select one)

- Very often
- Often
- Occasionally
- Rarely
- Never

Have you used your skills and knowledge from the training in one or more of the following ways?

- Writing articles about seed supply
- Giving advice to others about their seed supply activities
- Leading formal training activities
- Developing new activities for seed supply
- Conducting research on new methods for seed supply

How have you practised and improved the skills acquired during your training?

Information compiled by:

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Chapter 5:

Information Sources

Summary

5.1 What information is important for a good seed system?

Within a well-functioning seed system, both the seeds and certain information about them are distributed to end users. Three types of information are important: **technical information**, **economic information** and **information about partners within networks**. Technical information acquaints farmers with the advantages and disadvantages of various production options and informs plant breeders, public agencies and merchants about farmers' requirements. Economic information determines which inputs farmers are willing to use and which products are brought to the market. Information about the expected performance of partners, for example, their reputations and trustworthiness, determines the willingness of farmers, merchants and consumers to enter into transactions.

Quality tree seed is always accompanied by information. Since seed systems range from highly centralized to highly decentralized systems, the information needs for a particular seed system vary.

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5.2 What information is needed for a centralized seed system?

Within a centralized tree seed system there is one institution, often the national tree seed centre (NTSC), that collects, produces and distributes all tree seed. The central institution needs information on practices of collection, production and distribution of good-quality seed of priority species. The information needed outside the central organization focuses on establishing trees after seed is received. Nursery manuals are a typical information product distributed outside the central institution.

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5.3 What information is needed in a decentralized seed system?

In decentralized seed systems, many actors are involved in fulfilling such different roles as breeding, multiplying, processing, storing, distributing and marketing that are required for seed collection, procurement and distribution. Often some of these roles are taken up by small-scale entrepreneurs, such as tree seed collectors or nursery operators.

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5.4 What role can the public sector play in a decentralized seed system?

The government should support transmission of information between all the actors in the tree seed system, including producers, distributors, researchers and customers. Information services that the public sector should provide include market information, forums for information exchange, certification of tree seed (for example, through ‘truth in labelling’ or similar voluntary certification schemes), identification of seed sources, and species selection (lists of species and maps of locations suitable for particular species).

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5.5 What role can the public sector play in certification?

The public sector can either certify each seed lot, or certify seed suppliers. In the latter system, the public sector conducts random checks of registered seed suppliers, comparable to random checks for doping in sports. The advantage of this system is that it is cheap and fast, but the disadvantage is that it does not ensure the highest quality of seed.

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5.6 In which format is information best provided?

Information is provided to actors in the seed system through extension and training. Chapter 3 discusses extension in depth and how it brings information to farmers, while chapter 4 deals with imparting information and knowledge to actors in more formal settings.

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Introduction

Within a tree seed system not only seed is distributed. It is necessary to distribute information about the seed as well. Without appropriate information, a tree seed system's ability to provide adequate amounts of quality tree seed in a sustainable manner is not assured.

This Toolkit has been compiled as a primary source of information on the sustainable provision of quality tree seed. Other primary sources of information come from the experience and knowledge of the various actors in the tree seed system. Only through sharing information among the various actors can a well-functioning seed system be developed.

5.1 What information is important for a good seed system?

A well-functioning tree seed system is described thus: "A well-functioning tree seed system uses the appropriate combination of formal, informal, market and non-market channels to stimulate and efficiently meet farmers' evolving demand for quality seed" (Maredia et al., 1999).

Within a seed system, both seed and information are distributed from the point of collection to the end users. The technical chapters in this Toolkit describe how **quality tree seed is always accompanied by information** (see part II). The quality of the information contributes to the overall quality of the tree seed. As information is crucial for a seed system, appropriate attention needs to be given to gathering and distributing it.

Seed systems range from highly centralized to highly decentralized. Therefore, the information needs for particular seed systems vary. The information needs of different types of systems are described in this chapter.

5.2 What information is needed for a centralized seed system?

Within a centralized tree seed system, one institution collects, produces and distributes all tree seed (see chapter 1). Within many tropical and subtropical countries, an NTSC has been established to fulfil these roles. The NTSC usually has the national mandate for production and distribution of seed. Because of the national mandate, a strong distinction can be made between information that is needed within the NTSC, and information that is needed outside the NTSC.

The information required within an NTSC is produced by and for its staff as part of the daily work routine. Many NTSCs have produced large amounts of valuable information that is available in booklets and research papers.

For example, most of the information provided in Part II of this Toolkit was originally produced by projects that involved NTSCs. As another example, the posters provided on the CD-ROM that accompanies this Toolkit were produced by the Indonesian Tree Seed Project in collaboration with the DANIDA Forest Seed Centre. In many cases, the NTSC conducts research on specific tree species to enable seed of those species with good physiological and genetic qualities to be provided to its customers. Often the research is targeted at important tree species that are difficult to handle. The information that is needed inside the NTSC is therefore focused on guidelines to produce good-quality seed.

As it is expected that all seed within a centralized tree seed system will originate from the central institution, the information that is needed outside the NTSC is focused on establishing trees after seed has been received by end users. The information required outside the NTSC is therefore concerned with seedling production (as in nurseries) and planting. The nursery manuals produced by ICRAF and many other organizations are typical examples of such information (see Toolkit CD-ROM).

5.3 What information is needed in a decentralized seed system?

As seen in chapter 1, in decentralized seed systems many actors are involved in fulfilling the different roles (such as breeding, multiplying, processing, storing, distributing and marketing) required for seed collection and distribution. Often some of these roles are taken up by small-scale entrepreneurs, such as tree seed collectors or nursery operators. A decentralized tree seed system typically has a large number of widely scattered customers, including NGOs, small nursery enterprises and individual farmers.

Because of the many actors involved in a decentralized system, information exchange is crucially important for the system to work efficiently. Three types of information are important: technical information, economic information and information about partners within networks.

5.3.1 Technical information

Technical information acquaints farmers with the advantages and disadvantages of various production options and informs seed and seedling producers, public agencies and merchants about farmers' requirements. Farmers need to know what species are available for production of, for example, fruit, how much it costs to grow the trees that produce the fruit and how productive such species are in a particular environment.

A well-functioning tree seed system therefore requires the availability of varieties that can meet the requirements of farmers, and also requires that farmers are well-informed about the availability of these varieties. At the same time,

the technical information should enable actors to fulfil their specific roles in producing good-quality seed. NTSCs in many countries have carried out research and published technical information as a national and international public good.

5.3.2 Economic information

Economic information determines which inputs farmers are willing to use and which products are brought to the market. Farmers need to know the potential economic production of various species and which economic inputs are required. Farmers also need to know the potential markets for these products. Economic information should also focus on the sustainability of seed supply in relation to the need to maintain the quality of tree seed they require and information on where to get the seed.

5.3.3 Information about partners

Information about the expected performance of partners (their reputations and trustworthiness) determines the willingness of farmers, merchants and consumers to enter into transactions.

The formal laws, policies, regulations and informal conventions of market behaviour and social interaction are often described as the **institutional environment** (see chapter 1).

5.4 What role can the public sector play in a decentralized seed system?

The public sector could play a supporting role to a decentralized tree seed system. As explained in chapter 1, it is best for the various partners involved in the tree seed system to come together and agree on a common strategy for tree seed collection and distribution. Some suggestions are provided for the roles that the public sector can play.

An area in which the public sector has traditionally provided support is extension services that bring information to farmers (see chapter 3). The government could also support the transmission of information between all the actors in the tree seed system, including producers, distributors, researchers and customers. The state can often help to overcome the difficulties of organizing information exchange among large numbers of farmers and their access to that information.

Some information services that the public sector could provide include a market information system, forums for information exchange, identification of seed sources, certification of tree seed (sources), and species selection (lists of species and maps of locations suitable for particular species).

5.5 What role can the public sector play in certification?

Within a decentralized system, it is not seen as the sole responsibility of the NTSC to collect and distribute every single seed (see chapter 1). In some countries, the role of the NTSC is shifting from centralized collection, production and distribution of tree seed to a role of certification within a decentralized system.

Certification is an issue high on the agenda of many NTSCs and plant inspectorates. Certification ensures that the planting material circulating within a country reaches a minimum quality standard.

Various systems of certification have been proposed. Within one system, all the seed still passes through the NTSC, although it was not originally collected and produced by the NTSC. The advantage of this system is that the quality of the tree seed can be tested by the best possible procedures. The disadvantage of this system is that it is slow and expensive, as the seed needs to pass through the NTSC.

A voluntary system can be set up such that entrepreneurs wishing to collect and produce tree seed and seedlings register with the NTSC. As part of the registration, entrepreneurs declare the quality of tree seed that they wish to provide (for example, 60% germination capacity). The NTSC then provides information about the new supplier, including their contact data and their quality rating. In this system, it is the supplier that is certified. The NTSC then proceeds to make random checks on such suppliers. Once a supplier fails the tests, his or her name is removed from the lists of possible producers. You could compare this system with systems developed in sports, for example, athletics, where not every athlete is checked for drugs after each competitive event. Such seed systems currently exist for crop seed in Nepal, India, and South Africa and possibly other countries too. The advantage of this system is that it is cheaper and faster than systems where all the seed needs to pass through the NTSC. The disadvantage of the system is that abuses are still possible. Within this system, seed will not always be of the best quality, but this may be the only option of combining criteria of sustainability with quality.

5.6 In which format is information best provided?

Chapter 3 explains different approaches to extension. Extension is a non-formal education that aims to reach people in their own context and life situations. Through extension services, people identify and assess their own problems and needs, how to cope with them and how to solve them. To ensure the success and sustainability of extension programmes and any development venture, the active participation of the beneficiaries is important. Chapter 4

explains how to assess knowledge in larger organizations and how to identify training needs.

A large amount of relevant up-to-date information is available from the Toolkit CD-ROM. However, the tree seed and seedlings sector in many countries is in transformation and many new developments are likely to occur. New learning experiences are expected, but this new information may not be easily accessible to individuals. Users of this Toolkit are therefore encouraged to notify ICRAF whenever they become aware of new sources of information.

These three websites are likely to contain follow-up information on seed and seedlings systems.

World Agroforestry Centre (ICRAF):

<http://www.worldagroforestrycentre.org>

DANIDA Forest Seed Centre (now Danish Centre of Forest and Landscape)

<http://www.sl.kvl.dk/?lang=en&>

Food and Agriculture Organization of the United Nations (FAO):

<http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?geoId=0&langId=1&siteId=1820>

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Chapter 6:

Species Selection

Summary

6.1 Why is species selection important?

You need to select the species with which you work because your resources will not allow you to work with all species that can be grown in your area. Not all the species that can grow in your area meet the farmers' needs. You lose valuable resources and time when you choose a less desirable species.

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6.2 What attributes can I use to select species?

- Select species that are suitable for the ecological conditions of the planting site.
- Select species that address one or several needs of farmers.
- Select more than one species so that you can offer farmers a list of species to choose from.
- Select species for which planting material of good quality is available or can be produced within a reasonable time frame.

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6.3 How can I select species based on environmental conditions?

In many tree species, various provenances (trees of the same species that grow at the same place) differ in their ecological requirements. Trees from a certain provenance will only grow well under specific environmental or ecological conditions. As a general rule, you should plant trees in environmental conditions similar to those where their seed was collected, unless you have information that the trees will perform well under different conditions. You may want to use agroecological zones, tree seed zones or vegetation maps to find out where a particular species or population can be planted. As an alternative, you can find out growing conditions from databases such as the ICRAF Agroforestry database or the CAB International's (CABI's) Forestry Compendium.

For many tree species, the potential distribution has not been well investigated (see chapter 5), and therefore, the introduction of species to new areas should be treated with care. When you introduce a new species, make sure that you introduce enough genetic diversity (see chapter 8). Introduce the necessary

beneficial associated species, such as rhizobia, mycorrhiza and pollinators, without introducing any invasive species.

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6.4 How many species should I select?

It is always good to select several species in order to give farmers a wide choice. You also protect yourself better against disasters and price fluctuations when you select several species.

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6.5 How can I use socio-economic information to select species?

Species that are ecologically suitable for a certain area can be ranked in terms of farmer preference. This approach narrows down the list of species.

Information from specialists may be used to modify preference rankings obtained in farmer surveys. You may, for instance, have information about an emerging market for a specific use or species, or foresee a major environmental service that will be required in the future.

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6.6 How can I select species to increase tree diversity?

If you want to increase the diversity of a landscape, conduct a tree diversity survey to find out about the diversity that is already present.

Diversity refers to two aspects. The first is the number of species that you have in your landscape. The other is the number of trees of each species, and whether this number is equal or very different among the component tree species. You can increase diversity by increasing the number of species or by increasing the equality in tree numbers of the various species.

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6.7 How do I avoid introducing invasive species?

You should consult lists of invasive species. You need to inform yourself, as you may be held liable if you introduce an invasive species. Check with the plant health inspection services that issue import permits or with other specialists for lists of such species.

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Introduction

The selection of species is a stage that is often neglected by initiatives (such as tree planting projects or the efforts of a private nursery operator) that aim to promote species in a certain area. Trees of a certain species cannot grow everywhere, and not every tree species provides the same types of products and services. When you do not match the ecological and socio-economic conditions of the species and the planting site, the impact of tree planting may be very limited. Species selection is very similar to the selection of crop varieties: both farmer needs and the ecological conditions of the planting site need to be considered.

6.1 Why is species selection important?

There are many tree species, but only a small number of them may meet the needs of both the farmers and the planting site. Together with farmers, you need to select the species with which you work because your resources and farmers' needs do not allow you to work with all species that can grow in your area. When you choose a less desirable species, you lose valuable resources and time. For example, *Azadirachta indica* (neem) will not grow, or grows only very slowly, in highland areas. A tree-planting project that focuses on introducing neem in a highland area is therefore likely to fail, and it would be better to promote a species that will grow well in highland areas.

6.2 What attributes can I use to select species?

The attributes presented in this chapter include:

- Select species that address one or several needs of farmers.
- Select species that are suitable for the environmental conditions of the planting site.
- Select more than one species so that you can offer farmers several species for the same purpose.
- Select species for which good-quality planting material is available or can be produced within a reasonable timeframe.

You could interpret these criteria in a hierarchical way. The environmental conditions of your planting site could yield a list of all suitable tree species. Selections could be made from this long list based on the socio-economic preference ranking of species, and considerations of diversity. In some situations, you could come up with a list of the species that could provide the goods or services that are required, and shorten the list by ecological requirements afterwards.

It is very important that the selection of species is done together with local communities and that the selection procedure is transparent.

6.3 How can I select species based on environmental conditions?

In many tree species, various provenances (trees of the same species that grow at the same place) differ in their ecological requirements (see box 6.1). These differences are caused by the differences in the evolution of trees from different provenances, so that trees that have grown under particular conditions for a long time will be better adapted to those conditions.

As a general rule, when a tree species occurs under different environmental conditions, then the different provenances or populations could be effectively treated as different species.

A tree species will only grow well under specific environmental or ecological conditions. Environmental conditions that may be important for a certain species could be specific ranges in temperature, rainfall or soil type. Some species can withstand a wide range of environmental conditions and could be described as adaptable (or generalist). Other species are specialists that can only grow under a very limited range of environmental conditions. In addition to these two broad categories, species with wide tolerance may in fact consist of different populations that are specialized to different parts of the environmental range. It is therefore a good precaution to source your seed from environments that are similar to the environment in which you intend the seedlings to be planted.

Information on the average rainfall, the seasonality of the rainfall, the length of the dry season, average temperature, temperatures of the hottest and the coldest months and of the soil may be sufficient to describe the environmental conditions suitable for a certain species. It may be especially important to look at the frequency of extreme conditions such as drought, frost or high salinity. When you know the conditions under which a species can grow, you will have an idea of the environmental niche of that species. Microclimatic factors may be important: some species that require more rainfall could grow well in the wetter parts of a drier landscape, such as in valley bottoms or along rivers.

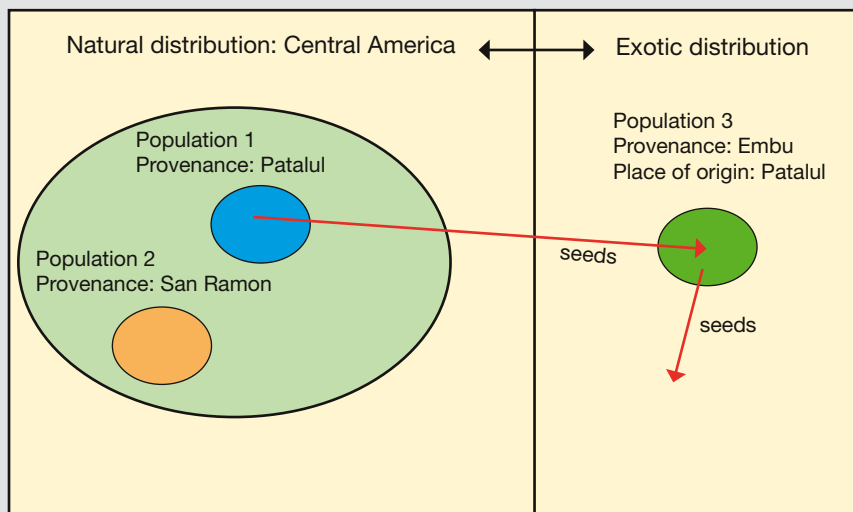
There will typically not be fixed limits to the environmental conditions for a species, with good growth within the limits and no growth outside the limits. There will normally be a transition zone where the species will still grow, but not optimally. For example, a species may grow best between 1000 mm and 1500 mm rainfall, but may survive within the range of 500 mm to 2000 mm.

Figure 6.1 gives a hypothetical example of the growth and survival of two species. You can see that one species is an adaptable species that will grow with rainfall ranging from 100 mm to 2000 mm, whereas the other species is

Box 6.1 The difference between provenances and origins

A tree population is a group of trees that exchange pollen with each other. As a result, a tree population will have similar genetic information and the trees will be more similar to one another than trees that do not exchange pollen. The similarity in genetic information is a result of evolution and adaptation to the environmental conditions of the location.

The provenance is the location where a certain population occurs. In the graph, the three populations of calliandra can be referred to as the Patalul, San Ramon and Embu provenances. When you collect seed from population 1, then you should describe this as the Patalul provenance. When you collect seed from population 3, then those were collected from the Embu provenance.



It is important to differentiate between the natural and the exotic distribution of a species. In the example, the Embu provenance was established from seed that was originally collected from the Patalul provenance. When you collect seed from the Embu provenance, you should also provide information on the original population and provenance, which is referred as the 'place of origin'.

It may be important to assess how long a population has been growing in an exotic provenance. If a population has only recently been introduced, then the genetic information of the original provenance and the exotic provenance may be the same. If you want seed of the exotic provenance, then you will also be able to obtain seed from the original provenance with the same genetic information. In cases where a population was introduced a long time ago, then we can expect that the exotic population will have adapted to differences in environmental conditions in the exotic provenance. In this situation, the genetic information of the original and exotic populations will be different.

It is very important to have an idea of the number of seeds that were brought from the natural provenance. If few seeds were transferred, or the collection was made from few trees, then we may suspect that the genetic diversity of the exotic provenance may be very low. In this situation, it may be advisable to collect seed from the original provenance and not from the exotic provenance, even if you expect that the population in the exotic provenance may have adapted better to the conditions in the exotic provenance.

a specialist species that will only grow with rainfall ranging from 250 mm to 950 mm. Figure 6.1 also indicates the difference between optimal conditions and survival conditions: the generalist species will grow best when rainfall is between 350 mm to 1800 mm.

Figure 6.2 shows that the generalist species of figure 6.1 may consist of various populations that can only tolerate a more limited range in rainfall. Hence, it is best not to attempt to grow a population outside its native range.

Trials with *Eucalyptus* species have demonstrated that it is not possible to predict where a particular population of a particular species will perform best, but that provenance trials are needed. For about half of the eucalypt species, there is one population that performs best everywhere. For the other half, one population will perform best at one location and another provenance will perform better at another location. Even species that are taxonomically very close can show these two behaviours. **The key lesson is that it is not possible to predict how a particular population will perform outside its native range.**

Because there are about 50,000 tropical tree species, we do not yet know the environmental range for most of these species and their different populations. For many species, we do not have good information on their distribution.

Figure 6.1 Hypothetical example of the survival percentage of a generalist species and a specialist species over a rainfall gradient.

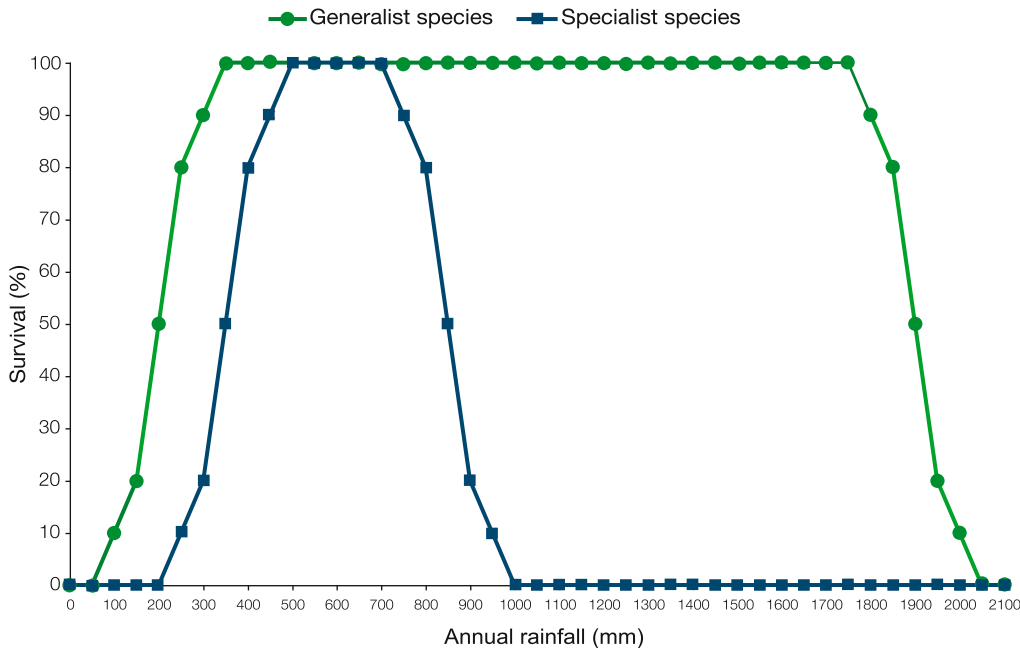
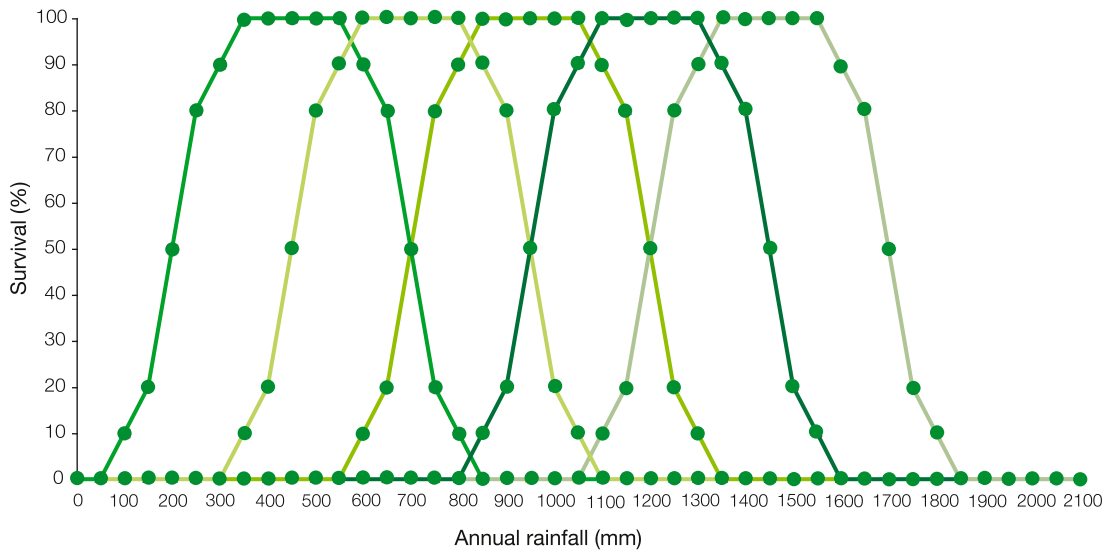


Figure 6.2 Survival percentage of various populations of a generalist species. (This is a hypothetical example in reality, such graphs will be less symmetrical.)



Even when we have data on the distribution of a species, it may still be difficult to draw conclusions about the environmental niche of a certain species (even with software that is developed specifically for such purposes).

What can you do when you do not have a prediction of the geographical distribution of a species? One approach is to use agroecological zones and tree seed zones. In many countries, maps have been produced for the major agroecological zones and many NTSCs have made tree seed zoning maps that can be used to select seed sources for particular planting sites. Also, for several countries, maps of major vegetation types have been made, which can be used to estimate the natural distribution of some indigenous species. You should realize that these maps are produced for many species, and not for one particular tree species, but often the maps come with recommendations for planting of species in zones. You can find these maps in libraries of the institutions that produced them (such as the survey department, the agricultural research centre or the forestry department). Some institutions provide copies of the maps for sale, and in some cases you might even find online versions of such maps.

As an alternative, you could search databases, books, or species lists (see chapter 5). For the Agroforestry database, a simple module for predicting species distribution is available. You can also ask local specialists about suitable species for a particular area. These specialists could be foresters, ecologists or extension agents, but may also be tree nursery operators that operate within your target area. When you ask specialists, request that they do not mention just one species, but give you several species that are suitable. A specialist may otherwise only provide the names of the species that is most dominant in the area, or the species for which the highest demand is expected.

Some experiments have been conducted to investigate how species perform outside their natural range. Some species grow well, while other species grow poorly. These experiments are described as species or provenance trials (see box 6.1). The only way to determine the performance of a species or a particular population of a species outside their natural range is to test their performance by actually growing the trees in new locations. You could check whether farmers in your area have already tested some new species, as farmers will sometimes introduce new species. If you do not have the time and resources to conduct such tests, then you should assume that the species will not be suitable for the new area.

You need to take several precautions when introducing a tree species into a new area.

- Introduce enough genetic diversity of the species by collecting seed or vegetative material from a sufficient number of mother trees (see chapter 8).
- Introduce beneficial associated organisms, such as microbes that fix nitrogen in the roots, along with the species.
- Have a fairly good idea of how the species is pollinated to ensure that the species can be pollinated and make good seed in its new surroundings.
- Be careful not to introduce a weedy species (see question 6.7).

When you introduce a new species, treat this as an experiment, and document afterwards whether the species was performing well or poorly. Others will benefit from your research only if you document and safeguard your results.

If you avoid introducing an invasive species, introduction of an exotic species (a species that is not part of the natural flora of your area) is not necessarily a bad practice. Be aware, however, that exotic species sometimes perform better than native species. This is because the pests or diseases of such species have not arrived at the new location yet, or because local species are not so well nurtured as exotic species.

6.4 How many species should I select?

It is always good to select several species with which to work. One reason for this is that you provide farmers with a choice of species that they can plant. It may be difficult to select one species that will satisfy the needs of all people. Many farmers typically have many different needs.

Another reason is to protect against disasters. It is always possible that a new disease or pest will invade your area. In many cases, this pest will primarily attack one species. If you have introduced several species, then you may be better protected against such disasters. There is some ecological evidence that

ecosystems containing several species are better protected against environmental disasters for this reason.

Often, different species can complement each other. For example, some species may fruit in one season and other species in another season. There may also be a trade off between the quality of the product and the speed of growth.

There may also be economic reasons for selecting several species. Often, whenever a product is abundant, prices drastically fall. When you produce a range of products, you will be impacted less by differences in prices.

Selecting several species promotes the conservation of more species. In many countries, forests have diminished and are fragmented. For some species, insufficient trees are left in the forests to maintain the species' genetic diversity. Populations of trees are needed to ensure the conservation of these endangered species. By conserving more tree species, you may also conserve more of the other species that depend on trees for habitat or food. Hence, selecting more species helps to conserve more biodiversity. This is one of the approaches of ecoagriculture that seeks to combine farmers' needs with biodiversity conservation.

6.5 How can I use socio-economic information to select species?

Species that are ecologically suitable for a certain area can be ranked in terms of farmer preference. This approach helps to narrow down the list of species. In most cases, you will not be able to work on all the species that are suitable for your area. Therefore, you need to narrow the list of species. Preference ranking can be structured in various ways.

One way of structuring preference ranking is by structuring the farmers by target groups. You could distinguish between men and women, or between rich and poor farmers, and obtain preference rankings for each category. For example, in a certain village, the men may prefer eucalyptus and pine, whereas women may prefer avocado and mango. You could choose to focus on female farmers and select avocado and mango as the preferred species.

Another way of structuring preference is by the different ways the species are used, including providing such products as fruit, medicine, or timber, and such services as shade, boundary demarcation, or soil fertility replenishment. For example, men may prefer timber species and women may prefer fruit species. You could also opt to select a species based on rankings for both primary and secondary products and services, and then calculate an overall score. Try to get an understanding of the reasons why a certain species is preferred: for example, is the species preferred because of yield, some product characteristics, fewer problems with diseases, or easier marketing of the product?

Getting a feel for the relative differences among species may be important when you want to select several species. Obtain a score or rating for each species (such as a rating on a scale from 0 to 5) rather than a preference ranking. Only by using scores will you be able to get an idea of the differences between the species. The difference between the first- and second-ranked species may be small compared to the difference between the second- and third-ranked species, or the situation may be just the reverse.

Some people have used the *bao* game to obtain rankings of species from farmers. The technique is part of the larger toolbox of participatory rural appraisal (PRA). An example of using the *bao* game is provided in figure 6.3. The respondents use stones to provide the scores for a number of species. The advantages of the technique are that it is easy for respondents to change their preferences after having had a first go at rating species, and that others can see the preferences of the respondent. The technique can easily be adapted to arrive at a group consensus on preferences.

Note that information from specialists may be used to complement preference rankings obtained in farmer surveys. Farmers usually have a good understanding of the local and exotic species that can best provide the products and services that they need. However, farmers may not have such a good understanding of differences in the marketing potential of various species. Specialists in these areas may be able to provide some insights into their marketing potential.

Figure 6.3 Using the *bao* game to rate different species



Farmers are asked to indicate their preference of a species by choosing a certain number of stones

Specialists may, for instance, have information about an emerging market for a specific use or a particular species, or foresee a major environmental service that will be required in the future. Market surveys may be one way of modifying preference rankings. Surveys could be at local, regional or national levels, and should be carried out by an economist. One factor that should be considered is the elasticity of demand and supply, which is the tendency of prices to drop when production increases.

When you make a choice of species based on preference rankings, it is important that you check with farmers whether or not they agree with your choice. For example, some cultural factors may not have been considered. It could also be possible that some farmers have previously experimented with the species of choice and experienced problems.

A specific approach that uses priority setting to select species for domestication has been developed by ICRAF and the International Service for National Agricultural Research (ISNAR) (Franzel et al., 1996). Although this approach focused on selecting priority species for domestication, the methodology can be used for priority setting objectives other than domestication (such as selecting species to be promoted in a certain area).

Preference ranking exercises should be supported with additional information on other useful species that may not occur in your area but could potentially benefit farmers. In addition, it may also be useful to obtain an understanding of which species farmers are currently using for specific purposes. This will provide a benchmark for your introduction of new species.

6.6 How can I select species to increase tree diversity?

Tree diversity is important because it reduces risks. When you only grow one tree species, a pest or a disease may completely destroy it. If you plant two, three or more species, then your risk of not obtaining any products from the trees that you planted will be reduced. There are also economic risks associated with growing only one species: prices will usually drop drastically when the supply exceeds the demand for a certain product. You should therefore avoid overproduction. Select tree species that increase the diversity of a planting region.

You may want to differentiate between the tree diversity of a farm, and the tree diversity of a landscape. For example, farms may only have five species on average, but the entire landscape may have 50 species. If you have certain targets to increase the diversity, then you should be very clear as to whether these targets apply to the average farm or to the entire landscape.

To increase the tree diversity of a farm or of landscape, you need information about the diversity that is already present. Conduct a tree diversity survey to establish how many species and how many trees of each species are already there.

The concept of diversity refers to two aspects. The first is the number of species that occur in your landscape. The tree diversity survey will establish the number of species in your landscape. You may also have information on the number of species within different parts of your landscape. It could be that one village has one group of species, and another village has another group of species. In such a situation, the species composition is different. In this situation, introduce some species from the first village into the second village where they do not occur. The same can be done for the second village, leading to an increase in the diversity of both villages.

The second aspect of diversity refers to the number of trees of each species. This is described as ‘evenness’ and relates to equality in the number of trees of each species. The greater the evenness, the greater the diversity. If every species has a similar number of trees, then the evenness is very large. However, if one species has 95% of all the trees, then the evenness and diversity are very low. For example, the diversity will be lower in an area that contains 950 avocado trees and 50 mango trees than in an area with 500 avocado and 500 mango trees. In a situation of low evenness, you could keep the same number of trees and species, but substitute some of the trees of the dominant species with trees of the less-dominant species.

An interesting feature of increasing the evenness of species is that the same number of trees can be maintained in a landscape. Should the species that you observed be ecologically suited to the landscape, then you will not need to go through an exercise of investigating the ecological conditions of your planting site. It is highly likely that information on the species can be provided by farmer-to-farmer exchange of information, which has several advantages (see chapter 3).

6.7 How do I avoid introducing invasive species?

Some species that are introduced into a new area become invasive. Invasive species consume or prey on native species, overgrow them, infect or vector diseases to them, compete with them, attack them, or hybridize with them. Invaders can change whole ecosystems by altering hydrology, fire regimes, nutrient cycling, and other ecosystem processes. Often, the same species that threaten biodiversity also cause grave damage to various natural resource industries. Invasive species may be difficult to remove from agricultural areas, since they are often spiny, grow quickly and produce an excessive amount

of seed. Invasive species can also invade natural ecosystems. Ensure that the criteria you use to select a species (for example, during preference rankings) are not likely to select an invasive species.

A list of databases on invasive species is available from the Global Invasive Species Programme at:

<http://www.gisp.org>

A good example of a national website is:

http://www.agis.agric.za/agisweb/?MIval=/wip_n.html

In many countries, you need an import permit to import certain species since countries try to avoid introducing invasive species. Check with the plant health inspection services of your country for lists of invasive species, or with specialists on such species. You need to be aware, since you will be held liable if an invasive is introduced. In Kenya, for example, there is currently a case against the introduction of a *Prosopis* species.

You should also be careful not to introduce pests or diseases with seed or seedlings. For this reason, adhere to good plant hygiene during your tree management practices.

Selecting indigenous species gives you some safety against invasive species. Be careful however, since a species may still become invasive when brought from one ecosystem to another within the same country.

Some trees can become serious weeds that not only infest fields, but can also cause harm to the indigenous species that occur in natural ecosystems, and could lead to the local extinction of indigenous species.

Information compiled by:

Roeland Kindt

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PART II:

T **echnical guidelines in seed production**

Chapter 7:

Seed Sourcing

Summary

7.1 What is a seed source?

A seed source is where seed is collected (which is not necessarily a stand!). This may be an identified number of trees in a landscape (for example, identified trees on farmland or identified trees in a natural forest) or a group of trees from which you obtain seed. A good seed source should provide fast-growing, healthy, genetically diverse, good-quality seed and stable planting material. Note that not every seed source will provide good-quality seed.

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7.2 What are the best tree seed sources?

- All seed sources that meet certain standards to ensure seed quality and that match the environmental conditions of the planting site. Seed of the highest quality may be very expensive, so you need to balance quality and cost for your planting purposes. Low-quality seed should never be used.
- Sources that match the environmental conditions: you are always safe if you collect seed locally or nearby, from trees that are well adapted to the environmental conditions of the planting site.

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7.3 What are the general types of tree seed sources?

- Natural forest: naturally occurring populations of trees in forest and woodland that are used for seed production.
- Farmland: trees that have been planted or retained for the production of end products or services other than providing seed.
- Seed orchards: trees that are (from seed or grafted) planted in blocks specifically for seed production.
- Plantations: trees that are planted in blocks to provide services or other end products other than seed.
- Vegetative propagation: asexual plant multiplication through cuttings, grafting or micopropagation.

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7.4 How should I establish and manage seed sources?

- Seed sources should be managed to increase seed production and to maintain genetic diversity.
- The area should be well suited to producing seed of a particular species.
- Ensure that the seed source has at least 100 trees for seed production. The isolation distance from other trees of the same species should be between 200 m and 500 m. You may need to plant 400 seedlings to achieve a final stand of 100 trees after thinning.
- Seed production areas should be easy to access.

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7.5 What information on seed sources should accompany seed when it is distributed?

- Geographical location of the seed source.
- Geographical location of the original seed source in the case of a seed orchard or seed production unit.
- Ecology of the seed source (elevation, temperatures, rainfall, soil types).
- Ecology of the original seed source in the case of a seed orchard or seed production unit.
- Number of trees in the seed source.
- Age of the seed source.
- Size of the seed source.

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7.6 How do I source seed that is not found locally or that is difficult to get?

- Identify suitable local or international seed suppliers. NTSCs or extension services can assist in providing seed or lists of local seed suppliers. International seed suppliers can be found through ICRAF's Tree Seed Suppliers Directory.
- Send out requests for the seed you need with specifications of species, when you need the seed, how many plants you need to raise and a description of the environment at the site where the seed is to be planted. Send out the request well in advance of the planting period.

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7.7 How do I determine the quantity of seed required?

To determine the quantity of seed required, you need to know the number of trees that you want to grow. You will need to take into account the germination percentage after storage, and to compensate for losses in the field and nursery. You can express the quantity needed in kilograms, but it is better to express it in numbers of seeds since seed weights may vary.

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Introduction

The genetic quality of tree seed sources is the decisive factor for the success of any tree planting programme. Hence, seed sources have to be carefully identified and selected. The selection of seed sources is based on the assumption that the characteristics of the seed trees are likely to be transmitted to their offspring.

7.1 What is a seed source?

A seed source is a group of trees growing together from which you can collect seed. We differentiate between a group of trees, a seed stand, a population, a seed production unit and a seed orchard (see also chapter 1). Not every seed source provides quality seed that is suitable for agroforestry. Tree seed should have good genetic, physical and physiological qualities (see chapter 12).

The selection of seed sources is an important step on the way to successful on-farm tree planting. The best seed source is not always the nearest, the easiest or the cheapest.

Single trees are not suitable for seed collection. Even if they could provide the quantity of a seed you require, seed from such trees lacks the desired diversity. Isolated trees should be avoided during collection since they are at risk of having self-pollinated seed. Self-pollinated seed often has a high percentage of hollow grains and low germination rate, and its seedlings do not grow well.

7.2 Where are the best tree seed sources?

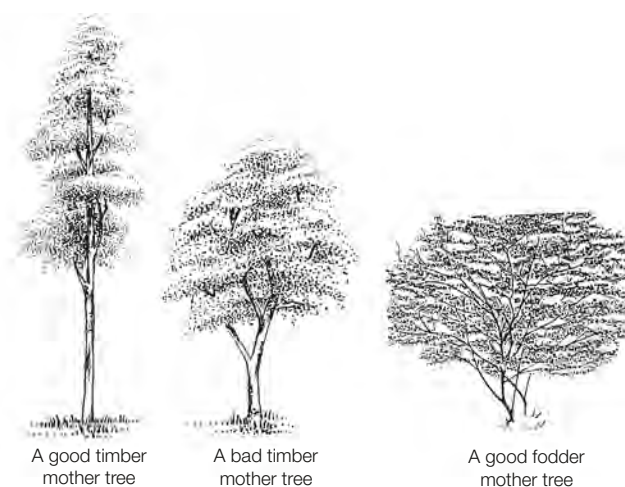
The best tree seed sources meet certain standards in terms of the number and quality of trees needed to ensure wide genetic variation and good seed quality. They also match the environmental conditions where the seed will be planted.

General suitability criteria for evaluating areas designated for seed sources could include:

- Is the seed source in the right ecological zone for seed production?
- Will the trees be well pollinated?
- Is the size of the seed source and the number of mother trees adequate?
- Are the trees healthy and their performance good?
- Is the accessibility and security of the source appropriate?

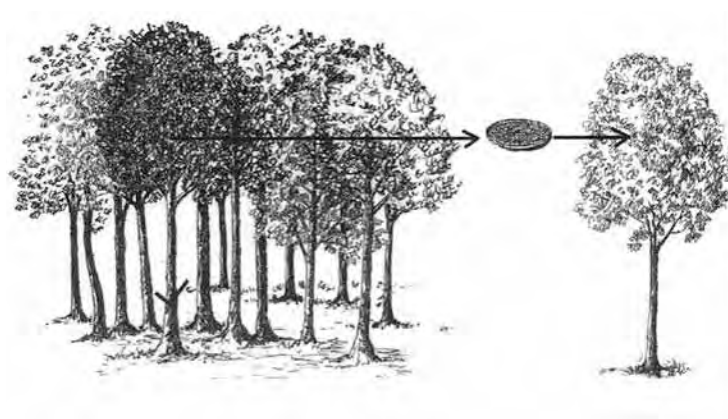
You should also pay attention to the age and the shape of the trees when selecting seed sources. Mother trees should have a good appearance for their intended end use (see figure 7.1). This also applies to the trees that surround them, as these could be fathers of the seeds that are collected and so affect the quality of the progeny (see figure 7.2).

Figure 7.1 Examples of good and bad characteristics for mother trees



Source: Tengnäs B., 1994.

Figure 7.2 When the seed (mother) tree is surrounded by other good-quality trees, the progeny will demonstrate good quality



Source: Mulawarman et al., 2003. 

Seed tree selection criteria differ for various tree types. For example, timber tree criteria could include:

- Straight stem form.
- Above-average tree height and stem diameter.
- Uniform crown without heavy branches or double stem.
- Long, clear marketable bole.
- Resistance to pests and diseases.
- Good-quality timber.
- Mature tree that produces ample quantities of seed.

Fodder trees and living fences criteria could include the following:

- Fast growing.
- High productivity of leaves and pods.
- Easy to coppice.
- High nutritive values of leaves or pods.
- Resistance to pests and diseases.
- Many branches.
- Multi-stemmed.
- Mature tree that produces ample quantities of seed.

Selection criteria for fruit trees could be:

- Abundant, sweet and big fruits.
- Uniform crown with low branches.
- Fast growing.
- Resistant to diseases and pests.
- Mature tree that produces ample quantities of seed.

For firewood, selection criteria could be:

- High calorific value.
- Fast growing.
- Easy to coppice.

7.3 What are the general types of tree seed sources?

There are four main types of seed sources (see chapter 1).

- Natural forest: naturally occurring populations of trees in forests and woodlands that are used for seed production.
- Farmland: trees that have been planted or retained in farmland for production of end products or services other than providing seed.
- Seed orchards: trees that are planted (from seed or grafted) in blocks specifically for seed production.
- Plantations: trees that are planted in blocks to provide services or end products other than seed.
- Vegetative propagation: asexual plant multiplication through cuttings, grafting or micopropagation.

7.3.1 Natural forest

International classifications of seed sources have been based on plantation forests where trees of the same species and age are growing together, the different types of seed sources have been classified according to their phenotypic appearance compared to an average stand of the same species in a given area. Such a comparison is very difficult to make in naturally growing vegetation where trees growing together are most often of different ages and species.

The most important criteria for evaluating seed sources in natural forest are:

- From how many mother trees will seed be collected? To collect enough genetic diversity, seed should be collected from a minimum of 30 trees.
- Can the mother trees be pollinated by pollen from other trees or are mother trees isolated? Pollinators should have good conditions for transferring pollen between trees.
- Identification of more than 50 trees is best since not all the seed trees will flower every year, yet you need to collect from at least 30 trees.
- The distance between seed trees should be at least 50–100 m. Trees have a higher chance of being more closely related at shorter distances.
- Avoid selecting isolated trees since they produce seed by inbreeding (or self-pollination), which often results in retarded growth and susceptibility to pests and diseases.

7.3.2 Farmland

- The trees may have been planted for other purposes, but you identify mother trees of a good phenotypic appearance. This refers to the observed characteristics of a tree, the sum of the attributes that result from interaction of the genotype and environment.
- Seed ideally needs to be collected from a minimum of 30 trees, but in some cases a single farmer will not have 30 trees of one species. In such cases, **collection should be done from several adjacent farms.** The greater the number of farmers involved, the better.
- Each farmer in a group should plant as many trees as possible on his or her land. More trees mean more genetic diversity, hence more variation in the seed produced and in the progeny. A greater number of trees of the target species is likely to make the area more attractive to appropriate pollinators. The more pollinators that visit the area, the greater the occurrence of cross-pollination.

7.3.3 Plantation forest

Plantation forest sources are those where trees are not specifically established for producing seed. Seed production is a secondary purpose for such stands. Sometimes, a particular seed stand is chosen as a seed source because of the good quality of its trees. The primary purpose of the trees may be the provision of timber, fuel or for soil conservation. The seed trees should be selected by comparing them with their neighbours. For instance, seed trees for a timber species should be straight, tall and disease or pest free. Small crooked trees with many branches should not be selected. This selection is applicable to such institutions as forest research institutes or government bodies.

7.3.4 Seed orchards

Trees planted specifically for seed production and/or breeding are known as seed production stands or seed orchards. A seed orchard is often established to

improve seed by selecting superior families or superior individual trees within families. A seed production stand is usually established only for producing seed. These sources are defined as ‘established seed sources’. Examples are shown in figure 7.3.

There are many types of seed orchard which vary according to the design of the orchard, type of planting material (from seed or from cloned material) and the number of families represented in the orchard. A ‘family’ is defined here as all the trees that are the offspring of the same mother tree, meaning that all these trees were grown from seed or clonal material that was obtained from the same tree.

7.3.5 Vegetative propagation

Clonal material is sometimes promoted because of its specific qualities such as growth rate or fruit quality. Two major considerations for clone material are: (i) there is a greater risk of your plant failing if only a few clones are used; (ii) this risk should be weighed against the benefits from growing clonal material.

7.4 How should I establish and manage seed sources?

7.4.1 Selecting the site

To maximize the genetic base and productivity of on-farm tree seed sources, the following approach for establishing them is recommended. Matching the planting site to the seed collection site may be necessary for optimal growth of trees (see chapter 6). The growth conditions of the planting site should match the growth conditions at the seed collection site. The altitude, latitude, longitude, rainfall, temperature, and soils should be appropriate for the target species. Seed collected from a lowland site should grow well when planted in lowland sites, and seed collected from the highlands should be planted in the highlands to ensure optimal tree growth. Note that the principles are just the same as those used in seed source selection or identification. If you plan to sell seed from the

Figure 7.3 Established seed sources



seed source, you should estimate the area of potential planting sites for the seed source, the number of potential customers in this area and how you can promote the seed from the seed source to the potential customers.

Local seed is safest. Collect seed at a similar altitude to the planting site or in a nearby seed source if one is not locally available, these trees should already be accustomed or adapted to the type of site where you want to plant, as shown in figure 7.4.

It is possible that trees raised from seed that is collected from a site with different conditions will still perform very well when planted at your location. This is why some research institutions undertake trials in different locations to test how trees from one location perform at others. Sometimes trees perform even better under conditions that are different from those of their natural environment. However, you need to have prior knowledge of the performance of a provenance in conditions similar to your environment before you can safely plant the material. For most tree species, we only have information on their growth under natural conditions, so you should only plant trees under the same conditions – unless you want to experiment and are prepared to take the risks involved.

7.4.2 Planting a seed source

Preferred spacing for optimum seed production will differ according to the species and site. Some recommended initial spacings for commonly encountered species are given in table 7.1. There are obviously many combinations

Figure 7.4 Matching the environmental conditions of the collection and planting site



Source: IFSP visual extension material, 2001. 

of spacing and planting configuration that can be used, some of which are shown in figure 7.5. As the trees grow larger, thin them, ensuring the best trees remain, to allow free crown growth and exposure to more sunlight. The recommended final spacings to encourage a large grown and maximum flowering are also given in table 7.1.

You can calculate the number of trees to plant per ha by dividing 1 ha (10,000 m²) by the space occupied by a single tree. For example, with a spacing of 0.5 × 0.5 m², we obtain 10,000 / (0.5 × 0.5) = 40,000 trees per ha. Similarly, you can calculate the number of seed trees that will remain.

When planted, the seed trees should be isolated from stands of unimproved trees of the same species to avoid pollen contamination. In this way, you maintain the genetic superiority of the seed produced.

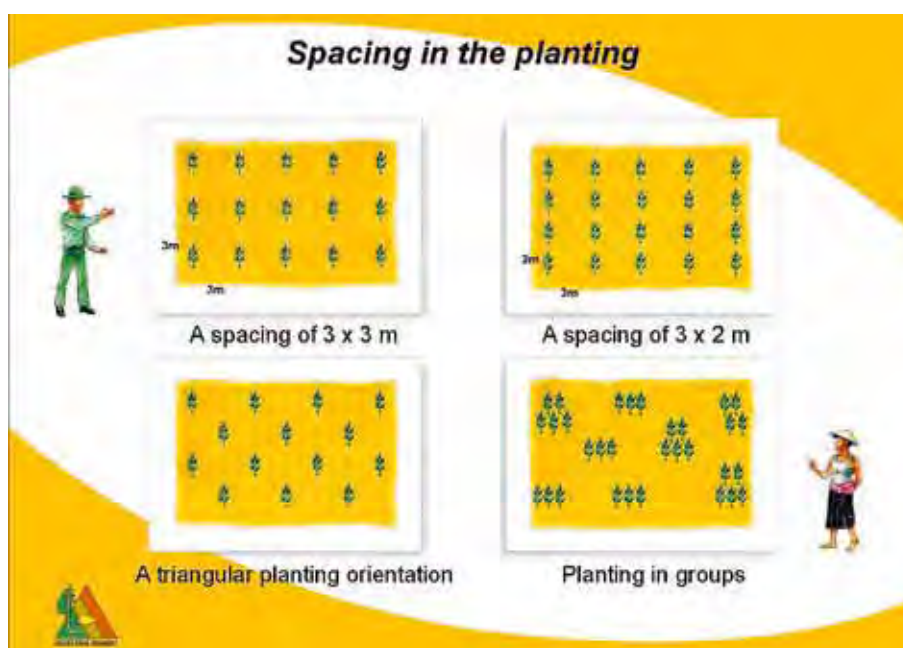
7.4.3 Seed tree management

Active management of trees will improve on-farm seed production. Management options include weed control around the seed trees, fertilizer application, opening up to allow free crown growth, pruning dead and non-productive branches, maintaining a clean understorey to facilitate seed collection (and reduce fire hazard), and implementing pest and disease protection measures.

Table 7.1 Recommended initial and final spacings for some commonly encountered tree species when to be used as seed sources

Species	Initial spacing (m)	Final spacing (m)
<i>Azadirachta indica</i>	8 × 8	5 × 5, 6 × 6, 8 × 4 or 8 × 8
<i>Calliandra calothyrsus</i>	3 × 3, 4 × 2 or 8 × 2	3 × 2, 3 × 3 or 4 × 2
<i>Crotalaria</i> spp.	0.5 × 0.5	0.5 × 0.5
<i>Gliricidia sepium</i>	3 × 3, 4 × 2 or 8 × 2	4 × 4, 8 × 2 or 3 × 6
<i>Grevillea robusta</i>	3 × 3, 4 × 2 or 8 × 2	3 × 6, 4 × 4 or 8 × 4
<i>Leucaena</i> spp.	3 × 2 or 4 × 2	3 × 2, 3 × 3 or 4 × 2
<i>Melia volkensii</i>	2.5 × 2.5, 3 × 3 or 4 × 4	5 × 5, 6 × 6, 8 × 4 or 8 × 8
<i>Moringa oleifera</i>	3 × 3, 4 × 2 or 8 × 2	3 × 6, 4 × 4 or 8 × 4
<i>Prunus africana</i>	4 × 4 or 5 × 5	5 × 5, 6 × 6, 8 × 4 or 8 × 8
<i>Sesbania sesban</i>	3 × 2 or 4 × 2	3 × 2, 3 × 3 or 4 × 2
<i>Tephrosia</i> spp.	0.5 × 0.5	0.5 × 0.5
<i>Vitex keniensis</i>	6 × 6	5 × 5, 6 × 6 or 8 × 4

Figure 7.5 Some examples of different planting configurations and spacings



Source: IFSP visual extension material, 2001. 

Seed tree planting on farms should be developed for multiple products and services and not solely for seed production. Seed trees can serve as shade trees, border trees, hedgerows, to improve soil fertility, bee-keeping or to enhance soil and water conservation. Seed trees, along with other trees, can also be managed to produce fodder, fuelwood, timber, fruit and other products, resulting in added total value for the farmer.

Dead seedlings should be replaced a few months after planting, for instance during the next rainy season. When the survival rate is more than 80%, the replacement of seedlings is usually not necessary; however, replacement must be done when the survival rate is less than 80% (see figure 7.6).

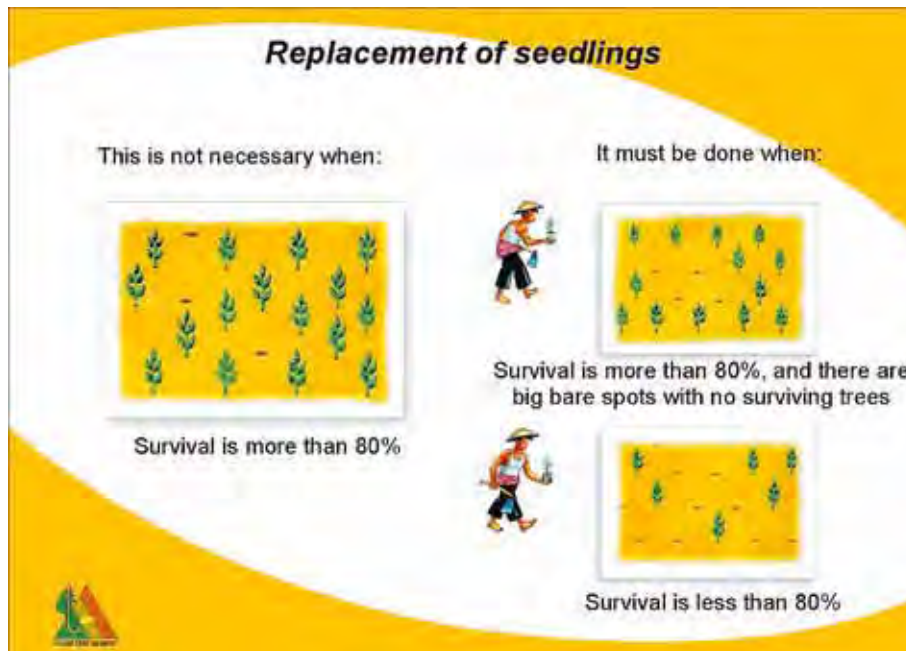
7.4.4 Establishment of small-scale seed production stands

Seed production stands or seed orchards should be established with at least 1000 plants derived from at least 30 different selected mother trees.

After thinning, at least 100 trees (genotypes) should be guaranteed at all stages of the seed production unit. The site for establishment should meet the requirements of the species in question for all ecological conditions. Ensure that land tenure or land use rights are secure.

The minimum size of the unit should be 0.1 ha to 0.25 ha, which corresponds to 4,000 to 10,000 trees planted at a spacing of 0.5 m × 0.5 m for species like *Crotalaria* and *Tephrosia*. For species that require a wider spacing such as

Figure 7.6 Replacement of seedlings



Source: IFSP visual extension material, 2001. 

4 m × 4 m (like *Prunus africana*, *Warburgia ugandensis* or *Melia volkensii*), the minimum size of the unit should be 0.5 ha, so that 350 trees can be established. These should later be thinned, leaving at least 100 trees.

The seed used for establishment should be collected from identified seed sources from superior trees. A moderate amount of intercropping will not hinder the health of the seed production stand and may even enhance tree growth.

7.5 What information on seed sources should accompany seed when it is distributed?

The movement of tree seed should ideally be accompanied by the following basic information on the seed source (see chapter 14):

- Geographical location of the seed source.
- Geographical location of the original seed source in the case of a seed orchard or seed production unit.
- Ecology of the seed source (elevation, temperatures, rainfall, soil types).
- Ecology of the original seed source in the case of a seed orchard or seed production unit.
- Number of trees in the seed source.
- Age of the seed source.
- Size of the seed source.

The location of the original seed source is important, since this determines the genetic characteristics of the trees. The actual location of the seed source can, however, influence seed production.

7.6 How do I source seed that is not found locally or that is difficult to get?

Identify suitable international seed suppliers through the ICRAF Tree Seed Suppliers' Directory or through NTSCs.

When you identify a supplier, send out a request in which you state the seed that you want. You should be specific on the species, the quantity of seed that you require and when you need the seed. When you provide information on the conditions of the planting site, the supplier may also be able to locate the best seed source. You should have a good idea of the quality of seed that the supplier handles. In case there is a doubt about the quality standards of a particular supplier, request seed samples.

Different suppliers may have seed of similar quality, but they may ask different prices for the same seed. In such a case, select the suppliers that provide the lowest prices. However, it is better to pay more for higher quality, since the trees that you obtain will grow better. 'Good-quality seed doesn't cost, it pays.'

The amount of time taken before the seed is delivered is also an important factor to consider. Sometimes seed is needed urgently, so a general idea of delivery or lead-times is necessary. In general, plan well ahead of the time that you want to plant the seed. If you miss one collection season, you may have to wait at least a year for the next! Request seed in time – to obtain the quality and quantity of seed that you require, the supplier will need adequate time to prepare your order. Additional collections may be needed if your request is for large quantities of seed.

When selecting a supplier the buyer should also consider after-sales follow-up, replacement of bad supplies, and other matters that could arise after the actual sale and transfer of seed is completed.

7.7 How do I determine the quantity of seed required?

The quantity of seed required can be determined fairly accurately if complete information about the uses to which the seed will be put is available. Seed for research is required in small quantities, with some variation depending on the experiment. Seed for dissemination activities is required in larger quantities.

When determining the quantity of seed required, basic information needed includes the area of land to be planted and the spacing at which the trees will be planted. Other factors to consider are the average level of purity of the seed, expected germination percentage for the species, and expected mortality of seedlings in the nursery and after planting in the field. You should also think of the thinning that you will do later.

For example, assume that you want 200 trees in your field. You may expect 20% of the trees you plant to die after planting and you want the surviving 80% to equal 200. Thus: if 80% of the trees planted equals 200, then 1% equals $200/80 = 2.5$. You therefore need to plant $2.5 \times 100 = 250$ trees. If half of the seedlings die in the nursery, you need to sow $250 \times 2 = 500$ seedlings in the nursery. With a germination rate of 25%, you need to order for $500/25 \times 100 = 2000$ seed. You can see from this example that if you had only ordered the same amount of seed as the number of trees that you wanted in the field, you would only have obtained 20 surviving trees.

If you know the weight of the seed, calculate the weight of seed that you require. However, it is better to order a specific number of seeds than a specific weight of seed. The reason for this is that seed weights for the same species may vary among seed sources or among years.

Seed arrives so that it may be sown immediately. You need to plan ordering, obtaining and sowing of seed properly so that as many as possible will produce seedlings. In the case of recalcitrant seeds, which cannot be stored (see chapter 10), you need to inform the supplier of the exact time when you require the seed.

Other seed can be stored for longer periods. Seed can be ordered at any time, but you need to ensure that your storage facilities are ready when you obtain it. Seed loses viability during storage (see chapter 10), therefore, you should adjust the number of seeds that you keep in store to meet the required number of trees that you want to plant.

Another reason to match the trees that you want to plant in a particular season with the seed that you keep in storage is that you want to save costs and storage space.

For buyers with basic laboratory facilities, the purity, moisture content and viability of a sample of the seed should be determined (see chapter 12). Apart from confirming the information provided by the supplier, these tests also enable the buyer to know what to expect when the seed is sown. Such information may also help to inform the supplier of the exact amount of seed to supply.

Information compiled by:

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Chapter 8:

Seed Collection

Summary

8.1 Where should tree seed be collected?

- Seed should be collected from a location with similar environmental characteristics to the planting site – such as rainfall or altitude – unless you have information that the trees species (or provenance) from a different environment will also grow well.
- Seed can be collected from a wide range of sources (see chapter 7), but basic principles of seed collection should be followed to ensure the quality of the seed is good (see question 8.7).

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8.2 What do I need to do before collecting seed?

- Obtain permission from whoever owns/has rights to the seed source.
- Check for any written information or available local knowledge for the species you plan to collect.
- Carry out a flower and seed survey – observe flower distribution, flowering period and differences in flower maturity of different trees.
- Observe the maturity of seed (more than 60% should be mature), and whether there are pests or diseases.
- Assemble a collection team. You can calculate the number of people that you need based on the amount of seed that needs to be collected, and the number of seed that an individual can collect.
- Obtain all the necessary equipment and materials.
- Organize transport and accommodation.

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8.3 When should I harvest the seed?

- Harvest when the majority (>60%) of the seed is mature.

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8.4 How do I tell when the fruits or seed are mature?

- Observe the colour change of pods or fruits.
- Carry out a cutting test to examine the interior of 100 seeds.

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8.5 How do I know how much to collect?

- Consider the number of plants that are needed.
- Estimate the number of seeds or plants that could die during storage, in the nursery or after planting.
- Calculate the cost of collection. Think of the distance to the seed source, the number of collectors, and how much they can collect per day.

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8.6 Is it better to collect from the natural forest or to buy seed from a farmer?

- It is good to collect seed from the natural forest (if the conditions of the forest are good) since the seed source is well known. Collect seeds from many trees to ensure their genetic diversity.
- If a farmer has collected the seed in a way that has maintained its quality and can provide all the documentation on the seed; then you may as well buy from the farmer instead of collecting the seed yourself.

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8.7 What are the basic principles of seed collection?

- Collect seed when trees are at the peak of seed production.
- In natural forest, collect seed from trees that are a distance of 50–100 m from each other to ensure genetic diversity.
- In farmland, it may be better to collect seed from trees of the same species from around 4 to 10 farmers who have land in the same ecological zone.
- Collect seed from at least 30 healthy mother trees and avoid isolated trees to maintain enough genetic variation.
- Collect equal amounts of seed from each tree to ensure that the genetic information of each tree is equally represented.

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8.8 How should tree seed be collected?

- There are various collection methods, which one is best under particular circumstances depends upon the amount of seed required, the type of tree and resources available. Appropriate safety measures should be in place.
- If you collect fallen fruits or seeds, make sure the ones you collect are healthy and free from insect damage.

- You can directly collect seed from smaller trees while standing on the ground or on the back of a vehicle, using tools such as telescopic shears, hooks or secateurs.
- You can also shake the trees and then collect the fruits or seeds that fall to the ground.
- You can collect seed from tree crowns using a ladder or a pair of climbing irons. For safety and effectiveness, seed collectors should be trained and should work in teams of two or three people when climbing trees.

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8.9 How do I handle fruits between collection and processing?

- Ensure they are protected from insects, birds, rodents and other animals.
- Fruit containing orthodox seed (see chapter 10) should be stored and dried in well-ventilated containers in a cool and shady place before extracting their seed. Suitable containers are baskets, loosely woven sacks or netting material.
- For recalcitrant seeds (see chapter 10) you need to maintain their high moisture content. The best option is to take the fruit immediately after collection to the place where the seed will be extracted. Alternatively, store the seed or fruit immediately in moist media and never keep them in the sun.

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Introduction

The physical, physiological and genetic qualities of seed must be maintained. Strictly following the rules of seed collection and seed handling will ensure this high quality. Always remember that bad quality seed will result in bad quality trees.

The choice of seed collection method depends on many factors, including the amount of seed required, the relative size of fruit or seeds, the number and distribution of fruits, fruit characteristics (including stage of ripeness), and characteristics of the individual tree, stand and site. Before seed collection starts, some important activities such as the identification of suitable seed sources, a flower and seed survey, and detailed planning for seed collection should be conducted.

8.1 Where should tree seed be collected?

Seed should be collected from a location with similar environmental characteristics to the planting site. Rainfall or altitude should be similar for both environments unless you have information that a species (or provenance) from a different environment will grow well (see chapter 6). Seeds can be collected from a wide range of sources (see chapters 1 and 7), but you need to follow the basic principals of seed collection to ensure that good-quality seeds are obtained (see question 8.7).

8.2 What do I need to do before collecting seed?

Before you do anything else you need to establish who is the owner of the seed source, and whether or not you need to obtain permission to collect seed. Once this is established and you have the necessary permissions you can then plan the rest of the collection process.

Prior to actual seed collection, find out if there is any existing written information and any available local knowledge about the species that may help you. Also carry out a flower and seed survey. Aspects of flowers and seed that you should check for are:

- Flower distribution among the trees and the flowering period.
- The degree to which individual trees flower at the same time.
- The expected amount of seed that could be collected.
- The maturity level of the seed.
- The level of pests and diseases on flowers or seed.

You should also have a detailed seed collection plan in place. In terms of planning the logistics of seed collection, you should:

- Verify accessibility of the seed source and transport needed.
- Determine what equipment and materials are needed, such as secateurs, canvas, polythene and netting sheets, cotton bags, canvas bags, sisal sacks, labels, hooks, lopping shears, ropes, ladders, protective clothing, machetes, binoculars, plant identification books, plant presses, newspapers, boxes for specimens, tags, field notebooks, pens, pencils, and a first aid kit.
- Assemble a collection team. Base the number of people that you need on the amount of seed to be collected and the method of collection.

8.3 When should I harvest the seed?

Harvesting should take place when the majority (>60%) of seed is mature. Details on how to determine seed maturity are given in the next section (question 8.4) and you can assess the percentage of mature seed using what is known as a crop rating system as shown in table 8.1.

8.4 How do I tell when the fruits or seed are mature?

Observe the colour change of fruits. For example, pods may change from green to yellow or brown when they are mature or cones may change from green to brown.

Sample at least 100 seeds or fruits picked randomly, then carry out a cutting test to examine the inside condition of the seed (see figures 8.1 and 8.2). Check the state of development or maturity and for damage by pests, diseases or other agents in the pods. A mature seed has a firm embryo, while immature ones have a milky endosperm or embryo. A legume seed is usually mature when it can no longer be crushed between the thumb and forefinger.

The cutting test can also be used to estimate the average number of mature seeds per fruit.

Table 8.1 Example of a crop rating system

Crop rating (%)	Crop description	Observations
0	None	No seeding trees
10–30	Poor	Fruit on some border trees and a few dominant trees inside the stand
40–60	Medium	Fruit on most border trees and on dominant trees inside the stand
70–90	Good	Almost all trees bear fruit (except suppressed ones)
100	Full	All trees bear fruit (except some suppressed ones)

Figure 8.1 Cutting test to determine seed vigour and disease infection



Figure 8.2 Cutting test of *Warburgia ugandensis* to determine maturity



8.5 How do I know how much to collect?

Consider the number of plants that you need. Estimate the losses of trees when seeds die during storage, when seedlings die in the nursery, and when plants die after planting in the field (see question 7.7). As you can see, you will need to collect more seeds than the number of surviving trees you want in the field.

Calculate the cost of collection. The cost of collection is determined by the distance to the seed source, the number of people involved, their productivity; their pay per day; and the amount of seed actually collected.

The most economical collection method is that of good-quality seed collected from carefully selected seed sources in well-planned collection expeditions, by well-trained personnel under professional supervision.

8.6 Is it better to collect from the forest or to buy seed from a farmer?

The advantage of collecting forest seed is that you are certain of the seed source and you know that the resultant trees will be well adapted to the local environment. You can also ensure that the seed is of good genetic, physical and physiological quality when you collect it yourself.

However, if a farmer has all the information on the seed source and can document collection in a way that demonstrates good quality, then you may as well buy seed from the farmer, instead of collecting it yourself. This is cheaper, and it also supports the collecting farmer's seed production effort. In the long run, it is a sustainable way of making seed available in an area.

8.7 What are the basic principles of seed collection?

In order to collect seed with wide genetic variation, seed collection activities should follow these principles:

- Collect seed when trees are at the peak of seed production (when the majority of seed is mature or has a crop rating of more than 60%). The first fruits that are produced are often not fully mature and may contain poor-quality seed.
- Ensure seed is collected from widely distributed trees, ideally 50–100m from each other, in order to ensure genetic variation in your collected seed. The closer trees are, the more likely they are to be related. In farmland it may therefore be necessary to collect from several adjacent farms (see question 7.3).
- Try to collect seed from at least 30 healthy mother trees. By collecting from many different mother trees, you ensure more genetic variation. When the genetic variation in your collection is small, you run the risk of trees growing poorly.
- When trees do not all flower and fruit in the same period, you may want to visit the seed source several times. Trees that flower at different times are

likely to have distinct genotypes, and you need to collect as many different genotypes as possible.

- You should collect from different places in the crown of a seed tree since the seed is more likely to have been pollinated by different fathers, thus providing more genetic variation.
- Collect equal amounts of fruits or seed from each tree. In this way, you will ensure that the genetic information of each seed tree is equally represented within the seed lot.
- Ensure that there are two labels (one inside and one outside the bag) on which the name of seed species, collection date, seed source and number of mother trees collected from are recorded. You may also include the names of the seed collectors, and the weight or the estimated number of seeds. This will help you remember where certain seeds come from (see chapter 14). Seed without documentation has a much lower value and quality, since there is no proof that it was collected according to the rules of good-quality seed collection.

8.8 How should tree seed be collected?

Seed can be collected using various methods. The choice of method depends on the growth form of the trees, the quality and quantity of seed required, and the logistics and experience of the collection team. Seed collection becomes more difficult, dangerous and expensive when trees are tall.

8.8.1 Collection of fallen fruit or seed

Collection of fruit or seed that has fallen from the mother tree is an easy and cheap seed collection method that is very applicable to trees established on farmland. Collection of fallen fruit or seed is often the best method for local use. However, this method has several disadvantages:

- Seed that have fallen are prone to attacks by pests or diseases. Often, the pressure of pests or diseases is greatest near the mother tree.
- You cannot be sure that the seeds all originated from the tree under which you collect, since animals and wind disperse some seeds over large distances. It is even possible that some seeds will have originated from other species, in which case the purity of your collection will be lower than 100%. This method should therefore not be used when basing your selection on the mother tree's superior characteristics. However, **collecting seed from the ground is a very good method when you want a random collection of seed from a wind-dispersed species.**
- Some seeds will die quickly after they have fallen, or will start germinating immediately and cannot be stored.
- It is almost impossible to collect small seed.

8.8.2 Collection from the crown of felled trees

You can collect seed from trees that are normally felled for other purposes such as timber. This is an easy and cheap method but requires that logging corresponds with the period of seed maturity.

The disadvantage is that, when you collect from trees that have been felled for a while, the fruits or seed are often too dry and many will have died. Obviously, felling the tree is a destructive method that does not allow for further collections from the same tree.

8.8.3 Collecting directly from trees without climbing

You can collect seed from some species while standing on the ground, on a small platform or on a vehicle. You can use telescopic shears, hooks, secateurs or ropes, as shown in figure 8.3.

Figure 8.3 Collection of *Sesbania sesban* with telescopic shears at Muguga site, Kenya



Often, you can collect more seeds if you shake the tree as shown in figure 8.4. The easiest way to collect seed from a shaken tree is to put a sheet, canvas or tarpaulin on the ground first. Fruits fall faster when their stalks are dry and brittle. It is therefore best to use this method around midday when air humidity is low.

Disadvantages of shaking a tree to collect seed are:

- It cannot be applied to every tree.
- Tree branches may be too high to access without climbing.
- Branches could break when you bend them.
- Small seeds may be dispersed too far away for collection, especially under windy conditions.

8.8.4 Collection from the crown by climbing

For this method, you climb the tree using either ladders (figure 8.5), a pair of climbing irons, a tree bicycle, or mountaineering ropes and equipment. Bamboo or aluminium ladders are easy to carry and safe if used properly.

Although farmers are often excellent tree climbers, it is better to use trained climbers to limit the risks. Using trained climbers and professional climbing equipment means that collection will be quite expensive. Costs could be limited by establishing a seed production stand after collecting from a minimum number of mother trees from the original seed source, or by collecting from trees in farmland that were established from the original source.

For safety reasons, collectors should work in teams of two or three when climbing trees. **A fall from a large tree can be fatal, therefore, it is very important to follow these safety regulations.**

Figure 8.4 Seed collection by shaking and pulling the branches of *Warburgia ugandensis*



Figure 8.5 Collection of *Eucalyptus saligna* capsules from the crown using ladder sections



- Climbers should wear a safety harness or hip belt, climbing line and safety line, as shown in figure 8.6.
- Climbers should be especially careful on trees with brittle branches.
- Collection should not be done next to power lines.
- Climbers should be physically and mentally fit and alert.
- Climbing equipment should be inspected for damage before use.
- People on the ground should also wear hard hats and be careful of falling objects such as branches, heavy fruit or climbing equipment.
- Climbers should be careful of wasps or bees.

The disadvantage of using ladders is that the tree stem needs to be relatively straight. When using sectional ladders, you should be able to tie each section to the tree.

For collection in the crown a pair of climbing irons (spurs) may be used. The disadvantage of using spurs is that there is a risk of slipping. Spurs should only

Figure 8.6 A seed collector in protective clothing and with seed harvesting equipment



be used on trees with thick bark and soft wood. The holes that spurs make in the trees could be entry points for fungi. Frequent collection from the same tree should therefore be avoided.

The disadvantages of using a tree bicycle are that the maximum circumference of the tree is limited to 80 cm and forks and branches in the tree cannot be passed.

8.8.5 Other collection methods

Some specialized methods include:

- Shooting down branches.
- Cutting branches with a flexible saw that is attached to two ropes.
- Using monkeys trained to collect seed.

8.9 How do I handle fruits between collection and processing?

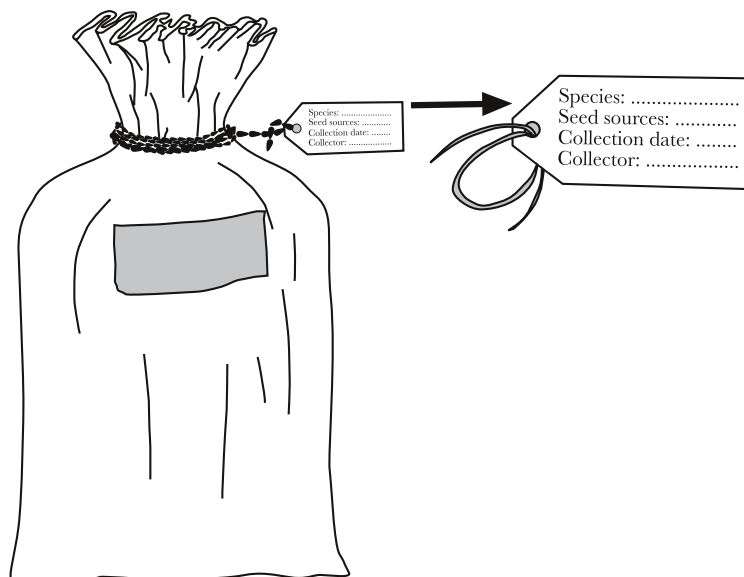
Store seed temporarily in good conditions and protect it from insects, birds, rodents and other mammals. Fruit or seed should be stored in a similar way to that used to preserve food for later consumption.

Freshly collected seeds within their fruits have moisture contents of around 15% (for orthodox seeds) and around 50% (for recalcitrant seeds) (see chapter 10). Fruit of orthodox seed should be stored and dried in well-ventilated containers in a cool and shady place. Suitable containers are baskets, loosely woven sacks or netting material. The sacks and baskets of fruit should be hung or stacked on planks to allow air circulation while awaiting seed extraction.

Recalcitrant seed must maintain a high moisture content to maintain viability. The best option is to bring the fruit immediately after collection to the place where seed will be extracted. An alternative is to have moist media for storage prepared at the collection site; for example, 2 volumes of moist sawdust for every 1 volume of fruit. The common practice of using polythene bags for the temporary storage of fruit should be avoided, since the fruit is likely to sweat and overheat, and the seed inside will die.

Each container of fruit must be labelled, as shown in figure 8.7 with at least the basic information (species, seed source, number of mother trees, and collection date). Always use two labels, one fixed to the outside of the container or bag and one fixed inside together with the seed. The labels and ink should be waterproof. If you lose the label on the outside of the bag, you can then still check the identity of the seed from the label on the inside. Seed without identity will lose most of its value as there will be no guarantee that it is of the right species and source (see chapter 14).

Figure 8.7 Seed labelling



Source: Mulawarman et al., 2003. 

Information compiled by:

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Chapter 9:

Seed Processing

Summary

9.1 Why is it important to process seeds?

- Seed processing is carried out to safeguard physiological and physical qualities of the seed.
- Seed usually forms part of the harvested fruit, therefore some form of processing is necessary to extract the seed from the fruit and to make it ready for storage or sowing.
- Seed processing reduces the storage space needed and makes sowing easy.

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9.2 What does seed processing involve?

- Sorting fruit.
- Removing seed from fruit (extraction).
- Cleaning and grading seed.
- Drying seed.

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9.3 How do I extract seed from the fruits?

- Select all mature fruit for extraction. Discard all the undeveloped fruit and any that are infected with insects or diseases. Fruit that is not fully mature can be kept separate to allow ripening.
- To extract seed from fleshy fruit soak the fruit in water for 1 or 2 days to soften the flesh. Then squeeze and rub the fruits against a wire mesh without crushing the seed. Add plenty of water while scrubbing and washing the fruit. The fleshy material will separate from the seed as it floats on the water while the seed sinks to the bottom. Seed of *Azadirachta indica*, *Dovyalis caffra*, *Tamarindus indica* and *Prunus africana* can be extracted by this method.
- Seeds with hard coats can be extracted from pulpy fruit by pounding. Fruit should be soaked for 1 or 2 days to soften the pulp, then pounded using a pestle and mortar. Fruits of *Melia volkensii*, *Melia azedarach*, *Scleercarya birrea* and *Cordia africana* can be extracted by this method.
- Non-fleshy fruits such as pods, capsules or cones can be dried in direct sunlight. Spread them in thin layers to allow good aeration and turn them over frequently and thoroughly. Most seeds in capsules or cones will easily open after drying, for example, *Eucalyptus saligna* and *Casuarina equisetifolia*.

- Other non-pulpy fruits need to be dried for 2–5 days, after which the fruit needs to be threshed to break it open and to obtain the seed. Species that need threshing after drying include *Leucaena* spp., *Calliandra calothyrsus*, *Acacia* spp. and *Sesbania sesban*.
- Some non-pulpy fruits with hard coats need to be dried for 5–7 days, after which the fruit is simply broken with a knife, hammer or stone to remove its seeds. Species that are processed this way include *Croton megalocarpus*, *Delonix regia* and *Swietenia macrophylla*.

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9.4 What other extraction methods can be used?

- Use of termites: Heap the fruit/pods in a sunken basin and covered with a layer of dry grass. Water the whole heap to attract termites and cover the heap with a black polythene sheet to keep it dark. The termites eat the fruit and leave the seed. Seed of *Prosopis juliflora*, *Terminalia brownii*, *Terminalia prunioides*, *Kigelia africana* and *Samanea saman* can be extracted by this method.
- Use of ruminants such as goats: Fleshy fruit and several indehiscent dry fruits are adapted to being ingested by animals. The animals digest the fruit and pass out the seed in their stools. Seed of *Melia volkensii* can be extracted by this method.

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9.5 How do I clean seeds?

Seeds can be cleaned by various methods including winnowing, screening or sieving, or flotation. The best method to use depends on the size and type of seed.

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9.6 How do I dry seeds?

Seed is dried by laying it out in the sun, but the method depends on the type of seed.

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Introduction

Seed processing should take place as soon as possible after fruit collection. Proper seed processing involves fruit sorting, extraction, cleaning, grading, and drying. Certain steps may be irrelevant for particular species or seed lots in some conditions. The purpose of seed processing is to extract the seed from the fruit, reduce bulk and maintain seed quality. If seed processing is not done correctly or soon, seeds may die.

9.1 Why is it important to process seeds?

Seed processing is carried out to safeguard the physiological and physical qualities of the seed.

Seed usually forms part of the harvested fruit, therefore some form of processing is necessary to extract the seed from the fruit and to make it ready for storage or sowing. Otherwise it may rot or be more prone to attack by pests.

Following extraction, the seeds are usually mixed with pieces of pulp, fruit walls or twigs and some seeds may be damaged or empty. All of these components are impurities that need to be removed.

Seed processing also reduces the volume of collections meaning that less storage space is needed and transport becomes easier. It also makes sowing easy.

9.2 What does seed processing involve?

Seed processing involves sorting fruit to eliminate undeveloped fruit and any fruit with pests or diseases, extracting seeds from the fruit, cleaning and sorting the seed and drying it.

Appropriate techniques that enhance and safeguard the physiological and physical qualities of the seed must be used. The most common methods are discussed in the following sections.

9.3 How do I extract seed from the fruit?

The first stage of processing is sorting mature fruit ready for extraction. All undeveloped fruit should be discarded, as should any that is infected with pests or diseases. Fruit that is not fully mature can be set aside to allow ripening and processing at a later date. Figure 9.1 illustrates fruit sorting.

Once the fruit is sorted then the seed can be extracted by one of the following methods depending on the type of fruit.

Figure 9.1 ICRAF staff sorting *Calliandra calothyrsus* pods



See also video clips on sorting seed in a barrel or on a tarpaulin. ☺

Depulping: This method can be applied to all fleshy fruit. Soak the fruit in water for 1 or 2 days to soften the flesh. Squeeze and rub the fruit against a wire mesh, taking care not to crush the seed. Add plenty of water while scrubbing and washing fruit to remove the fleshy material from the seed. The fleshy material will float while the seeds sink to the bottom (see also section 9.5.3). Seed of *Syzygium cumini*, *Dovyalis caffra*, *Trichilia emetica*, *Vitellaria paradoxa* and *Prunus africana* can be extracted by this method.

Pounding: This is another method for processing pulpy fruits but is only suitable for those with seeds with hard coats. Soak the fruits in cold water for 1 or 2 days to soften the pulp. Pound the fruits with a pestle in a mortar. Seed of *Melia volkensii*, *Melia azedarach*, *Sclerocarya birrea*, and *Cordia africana* can be extracted by this method.

Threshing: This method is used for non-pulpy fruit that opens when mature but whose opening is not wide enough to release the seed. Pods often show this characteristic. Figure 9.2 illustrates separating seed from fruit by threshing. The seeds may remain attached to the fruit after the process.

For some species, pods may not open when mature. However, when they are dried for 2–5 days, the outer walls become weak and brittle and break easily when threshed. Species that need threshing after drying include *Leucaena* spp., *Calliandra calothyrsus*, *Acacia* spp., and *Sesbania sesban*. Seed of *Grevillea robusta*, *Casuarina* spp. and *Eucalyptus* spp. can be extracted by spreading capsules on a canvas sheet or wire-mesh screen, then exposing them to the sun for 3–4 days. When the pods dry, they release the seed. Capsules are shaken by hand to accelerate seed release. The seeds should be protected from rain, birds and insects.

Figure 9.2 Threshing *Sesbania sesban* pods to facilitate seed extraction



See also video clip on seed threshing. 📺

Breaking open: Some fruits with hard coats need to be broken open. After drying for 5–7 days, fruits are broken open with a knife, a hammer or a stone and their seeds removed. Seed of *Adansonia digitata*, *Swietenia macrophylla*, *Delonix regia*, and *Croton megalocarpus* can be extracted by this method (see figure 9.3).

9.4 What other extraction methods can be used?

Termites can break down some fruit. Heap the pods in a sunken basin and covered with a layer of dry grass. Water the whole heap to attract termites, then cover the it with a black polythene sheet to keep the heap dark. It takes 3–7 days for the seed to be separated from the fruit. Seed of *Prosopis juliflora*, *Terminalia brownii*, *Terminalia prunioides*, *Kigelia africana* and *Samanea saman* are extracted by this method. This method is applicable during dry periods. This method has been used successfully in Kenya by the Kenya Forestry Research Institute–Japanese International Cooperation Agency (KEFRI–JICA) project in Kitui (a semi-arid area).

Figure 9.3 Fruit of *Adansonia digitata* need to be broken open to extract seed



Ruminants can ingest some fruits. Fleshy fruits and several indehiscent dry fruits are adapted to being ingested by animals. Seeds and stones are often left clean and intact after ingestion, although in some species a relatively large amount of seed may be digested. *Melia volkensii* fruits can be extracted by this method. Note that you will need to extract seed from dung if you use this method.

9.5 How do I clean seeds?

Cleaning and sorting helps to maintain high physiological and physical qualities. Following extraction, the seed is usually still mixed with pieces of pulp, fruit walls or twigs. Some seeds may be damaged or still empty. All these components are impurities that need to be removed. The best method of cleaning to use is determined by the seed size and type.

9.5.1 Blowing and winnowing

Blowing and winnowing work on the principle that the impurities weigh less than the seed. Wind blows away the lighter impurities, leaving good-quality seeds, as shown in figures 9.4 and 9.5.

Figure 9.4 *Sesbania sesban* – cleaning seed by blowing



Figure 9.5 *Sesbania sesban* – cleaning seed by winnowing



9.5.2 Screening or sieving

Seed is separated from impurities by differences in thickness or diameter, as shown in figure 9.6.

Figure 9.6 Sieving *Sesbania sesban* seeds



9.5.3 Flotation

This method is based on the principle that full seed is heavier than impurities. The good seeds will sink in water, while damaged or infected seeds float and should be skimmed off, as shown in figure 9.7.

9.6 How do I dry seeds?

Orthodox and intermediate seed (see chapter 10 for more information on the types of seeds) can be sun-dried in containers, as shown in figure 9.8. Seeds should never be dried on polythene sheets, since temperatures can easily rise above 45°C, killing the seed. Orthodox seeds can also be dried above a fireplace (smoke drying). Again care should be taken not to overheat the seed.

Figure 9.7 *Tephrosia vogelii* – cleaning seed by flotation



Figure 9.8 Sun-drying seed of various species



Recalcitrant seeds should be dried in the shade to retain a high level of moisture content (20–40%), in order to keep them alive.

Information compiled by:

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Chapter 10:

Seed Storage

Summary

10.1 Why should I store seeds?

Seeds are stored because it enables them to be:

- Kept in good condition until they are planted.
- Planted in later years when trees produce few seeds.
- Conserved for their genetic diversity.
- Held against increased demand from customers.
- Prepared for distribution.
- Protected against attacks by pests or by diseases.
- Retained for food security.

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10.2 How should I prepare seed for storage?

- In order to improve seeds' lifespan, dry seeds just before storage and as quickly as possible after extraction.
- **Consider the physiological storage classes as related to temperature and moisture content** for instance,
 - **Recalcitrant seeds** (sensitive to low moisture content and high temperature).
 - **Intermediate seeds** (sensitive to low temperature thus should be stored in conditions of high temperatures and low moisture content).
 - **Orthodox seeds** (not sensitive to low temperature or low moisture content but require proper storage).

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10.3 How long can I keep tree seed?

- Even under the best storage conditions, seeds that have died will not come back to life. **Handle seeds properly before storing.**
- The length of time that seeds can stay alive varies greatly by species, by different provenances of the same species and by storage conditions.
- At the farmer level, under fair to good conditions, the seed of many species will stay alive for 1 or 2 years. Such seed is called **orthodox** seed. Examples are *Acacia* and *Eucalyptus* spp.

- The seed of some species can only be stored for 1 or 2 weeks in ideal conditions. If these seeds lose moisture, they die. Such seed is called **recalcitrant** seed. Examples are *Syzygium cumini*, *Vitellaria paradoxa* and *Trichilia emetica*.
- Under the proper storage conditions, the seed of some species can be stored for 4 weeks. Such seed is called **intermediate** seed. An example is *Carica papaya*.

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10.4 How should I store orthodox seeds?

- Store the seeds in clean, dry and airtight containers. The volume of air in the container should be small in comparison to the volume of seed.
- Under ideal conditions, good containers for a medium storage period (<1 year) are metal tins, clay pots, and thick polythene bags.
- Good containers for a long storage period are thick polythene bags that are tightly sealed with wire and placed in tight, tough plastic containers such as drums, barrels, or plastic jerry cans. Other long-storage containers are gourds, glass jars that have a rubber lining and screw lid or glass bottles that have screw lids.
- The containers should be stored in a place that is cool, dark, dry and well-ventilated. The containers should not be placed directly on the floor.

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10.5 How should I store intermediate seeds?

- After seeds have reached an appropriate moisture level, store them in ambient conditions (normal surrounding temperature, humidity and light).
- Store them in a clean, dry, airtight container.
- Store them for a short period only (4–6 weeks) under ideal conditions.

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10.6 How should I store recalcitrant seeds?

- Ensure that the seeds maintain their high moisture content and are stored at an ambient temperature. Store the seeds for 1 or 2 weeks in permeable containers or bags to allow some ventilation.
- To maintain humidity, store the seeds in a medium (moist sawdust, peat or vermiculite) that is slightly moistened with distilled or de-ionized water. The ratio of seed to medium should be 1:2.

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10.7 How do I keep relative humidity low during storage?

- Put seeds in airtight containers and store them in a dark place.
- Store seed containers in a cool dry place and do not open them frequently.
- If containers are not completely airtight or if samples are frequently taken out, seeds may be stored with a desiccating chemical like silica gel or charcoal.
- If seed is to be removed on a regular basis, put it in several smaller containers rather than in one large container.

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Introduction

When seed is not kept under good conditions, it quickly dies. Seed can maintain viability for long periods if it is properly stored. This chapter describes good ways of keeping seed alive and proper seed storage.

10.1 Why should I store seeds?

Tree seed is stored for various reasons. All reasons for seed storage encompass some element of future use of the seed.

- The main aim of seed storage is to keep the seed **alive** and in **good condition**.
- Good seed years must be taken advantage of especially for species that only flower periodically. *Ocotea usambarensis* and Dipterocarpaceae for example, only flower once in several years. Similarly, many tree species do not produce the same amount of seed each year. Therefore, you may want to collect more seed in the year when production is high for use in years when production is low.
- Conserving genetic information: the threat of extinction to provenances and species necessitates taking measures to conserve seed genetic information. Long-term seed storage, for example, conservation of seed by the Millennium Seed Project of The Royal Botanic Gardens, Kew, is one of the important measures of genetic conservation.
- Preparation for the planting season: if the harvesting and planting seasons do not coincide, you may need to store seed to bridge the time between collection and sowing.
- Future demand: the demand for a certain species may be very low when you collect the seed, but may be higher than the production at a later time. Under these conditions, you need to keep some seed in stock so that you can buffer the differences between demand and supply.
- Avoiding deterioration: even if the time between collection and planting is very short, pests such as rodents, birds or beetles or fungi can attack the seed. You should store the seed in a place that is free from pests and pathogens.
- Security: another reason for storing seed even if the time between collection and planting is short is to keep them safe. Demand for seed can be very high, such that it raises the probability of seed being stolen.
- Food storage: You may wish to store seed so that you can use it at a later date as food. In some countries, tree seeds and fruits are eaten. Examples of such species include *Tamarindus indica*, *Adansonia digitata*, *Ziziphus mauritiana* and *Acacia* spp.

10.2 How should I prepare seed for storage?

Carry out seed drying just before storage and as quickly as possible after extraction. This helps to:

- Avoid seed deterioration in store and thus improve its lifespan.
- Reduce rotting of seeds in store.
- Improve resistance of seed to pests and diseases during storage.

Tree species are divided into **three different classes** according to the maximum period that their seed can be stored, taking into consideration their temperature and moisture content requirements. Note that in nature, species will show a continuous range in their maximum storage period. However, the three classes guide you on the best storage period for each species. **Note once more that the storage time depends on optimal storage conditions; under bad conditions, all seeds will die quickly.**

Recalcitrant seeds should be dried under shade to retain a high level of moisture content (20–40%), in order to keep them alive. The temperature at which the seed is stored should be around 12–15°C. Recalcitrant seeds cannot be kept for long under conventional conditions in seed storage containers. Examples of recalcitrant seed are *Mangifera indica*, *Persea americana*, *Syzygium cumini*, *Trichilia emetica* and *Vitellaria paradoxa*.

Intermediate seeds can only withstand a limited level of drying – to a moisture content of 15–19%. They are sensitive to low temperature, thus should be stored in high temperatures. Intermediate seeds cannot be stored for a very long time before losing viability. You should use shade drying or air drying methods that are suitable for seeds extracted from pulpy fruits. Air dry for 1–3 days before storing or plant the seeds immediately for better germination. Examples of intermediate seed are *Azadirachta indica*, *Maesopsis eminii*, *Dovyalis caffra* and *Artocarpus heterophyllus*.

Orthodox seed is commonly dried under direct sunlight for 2–3 days to a moisture content of 5–8%. The period of drying will depend on the relative humidity of the air, the species and the air temperature. Orthodox seeds can also be dried above the fireplace (smoke drying), or where farmers dry their firewood during the rainy season. You should be careful not to overheat and kill the seed. Orthodox seed can be stored for a fairly long period of time before losing viability. As a rule of thumb, for orthodox seeds, the mean viability period (seed life-span) doubles each time the moisture content is lowered 1% below the maximum 14–15% moisture content level that is acceptable for storage.

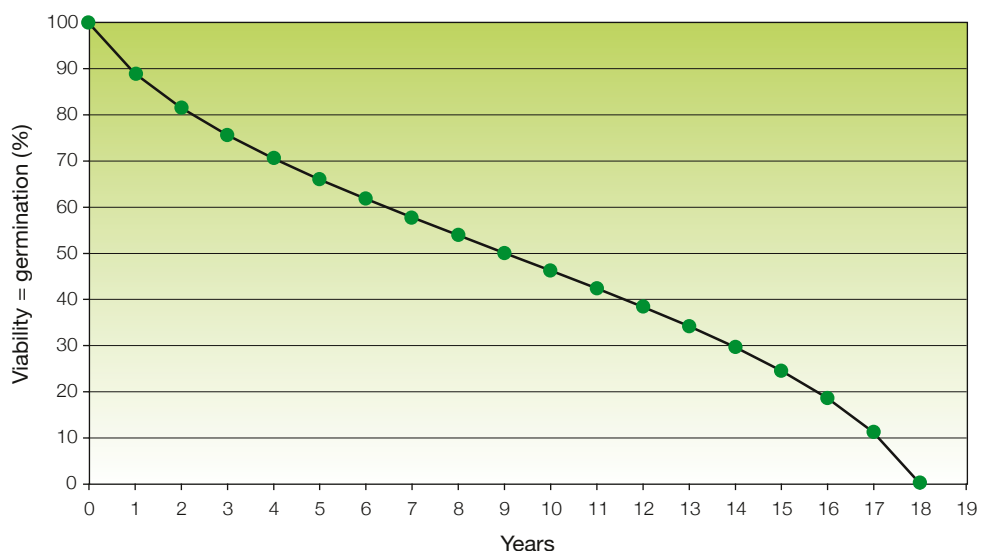
Seed can be treated against pests with locally available preservatives, for example, leaves of neem or the ash of any other tree species, before storage. Each container should have two labels – one inside and one attached outside with at least the species name, date of collection, number of parent trees, seed source, weight of seed and collector’s name.

10.3 How long can I keep tree seed?

The length of time that seed remains alive varies according to the species or the place where the seed was collected. The length of time also varies between seeds of the same species that were collected from the same place. This time also depends on morphological, physical, physiological and health conditions of the seed. The length of time that seed stays alive depends very much on the storage conditions – when storage conditions are bad, all seed dies quickly.

In general, seed loses viability as time progresses until ultimately, all seeds die. The viability of seed is expressed as the percentage of the number of seeds that germinate from the whole lot after a given period of seed storage. A general graph of the loss of viability of a collection of orthodox seeds is shown in figure 10.1. All the seeds will have died after 18 years; 50% of the seeds will have died after 9 years; whereas only 20% of the seeds will have died after 2 years. This is only an example – the period for which seed can be stored varies from species to species – some can be stored for longer than this and others for much less.

Figure 10.1 Viability of seeds over a period of 18 years



Note: All seeds will lose viability as time progresses. In this example, after 1 year, about 90% of seeds can still germinate, after 9 years about 50% will germinate and after 18 years all seed has died. This curve will be different for different species, even for different seed lots of the same species.

Seed that is stored under conditions that are less favourable to its survival will lose viability more quickly. Figure 10.2 shows how the same seed loses viability more quickly when stored under worsening conditions. The third curve, for example, shows that all seed will have died after 9 years, and 50% of it after 5 years. This is an indication of the importance of storing seed properly.

As mentioned above, the period that seed can stay alive depends a lot on the species to which it belongs. Some species (see figure 10.3) cannot be stored for long periods whatever the storage conditions. Other species can be stored for long periods so long as the storage conditions are good.

Figure 10.2 Viability of seeds over a period of 18 years under three worsening conditions

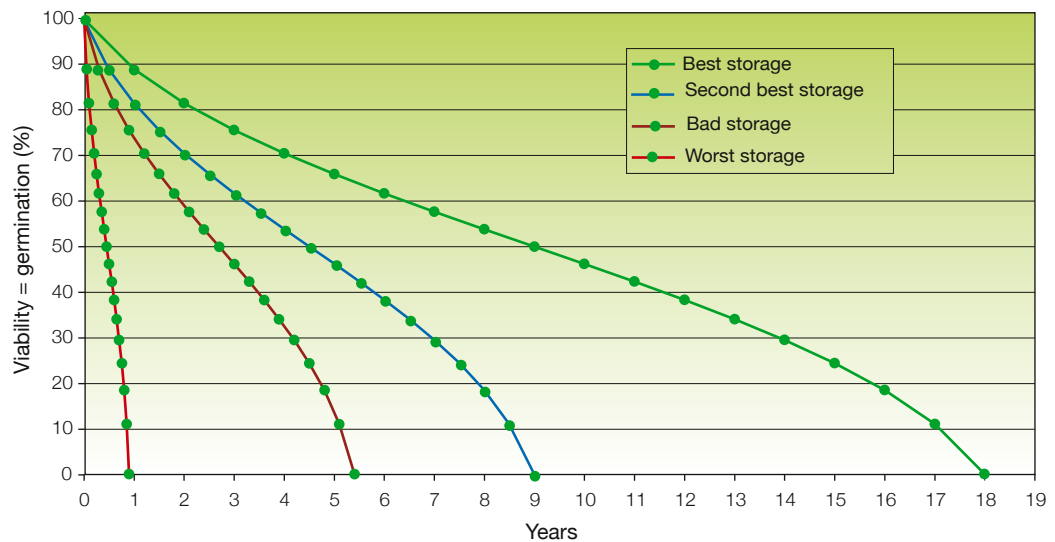


Figure 10.3 Recalcitrant seed of *Inga edulis* germinates even before the pod is harvested



10.4 How should I store orthodox seeds?

Orthodox seeds should be stored in clean, dry airtight containers (see figure 10.6). The containers should be properly filled with seed, and then closed off after the seed is put in. Gourds can also be used as seed storage containers (see figure 10.4).

If properly dried, orthodox seeds can be stored at room temperature. Most seeds can be stored for longer periods in refrigerated conditions (0°C to 5°C or even down to -20°C). Some hard-coated species can be stored at room temperature almost as long as when refrigerated.

Orthodox seeds of most species will remain viable for 1–2 years when stored under fair to good conditions at the farmer and NGO level. Viability can be extended by reducing seed moisture contents and by lowering the storage temperature.

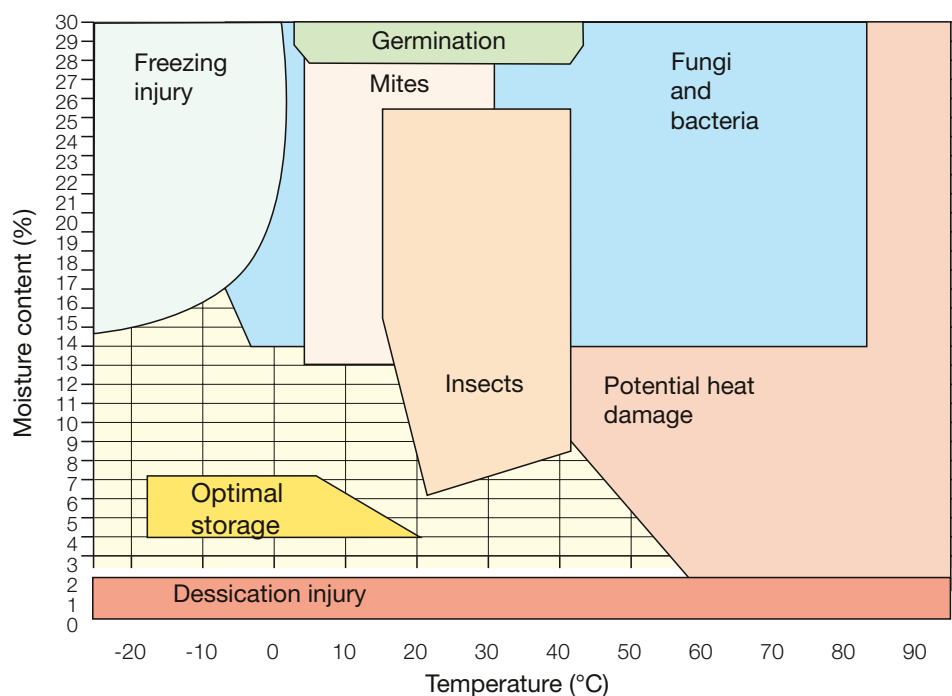
As a rule of thumb, the mean viability period doubles each time the moisture content is lowered by 1% below the 14–15% moisture content which is the maximum content for successful storage. In other words if the viability was 2 years at 14% then if you drop the moisture content to 13% it will be 4 years. Similarly, again as a rule of thumb, the mean viability period doubles each time the mean storage temperature is lowered by 5°C. This ranges from the highest temperatures encountered during the drying of orthodox seeds (50°C) down to 0°C. Figure 10.5 shows the relationship between seed moisture content and storage problems at different storage temperatures.

In general, orthodox seeds are stored at 5–8% moisture content and at temperatures of 0–5°C. See chapter 12 on testing for the moisture content of seed.

Figure 10.4 Using a gourd to store seeds



Figure 10.5 The relationship between seed moisture content and storage problems at different temperatures for orthodox seeds



Source: Thomsen and Stubsgaard, 1998.

10.5 How should I store intermediate seeds?

These seeds can withstand relatively low moisture contents (<12%), but they cannot withstand low temperatures (<5°C). After the seeds' moisture content is lowered, store them in a clean, dry, airtight container for 4–6 weeks at ambient temperatures. Do not store them in refrigerated surroundings.

10.6 How should I store recalcitrant seeds?

Recalcitrant seeds need to be stored at high moisture levels. They can only be stored for 1 to 2 weeks before losing viability. These seeds cannot withstand surroundings with low temperatures or low relative humidity. For short-term storage, put recalcitrant seeds in permeable containers to allow ventilation.

To maintain their moisture content, recalcitrant seeds should be mixed with a medium (sawdust, peat or vermiculite) that is slightly moistened with distilled or de-ionized water. Seeds and the medium should be mixed at a ratio of 1:2, and then stored at ambient temperatures and kept moist.

10.7 How do I keep relative humidity low during storage?

Orthodox seeds must always be kept in a well-ventilated cool, dark and dry place as shown in figure 10.6. The seeds' initial moisture content should be low enough to avoid respiration.

If small portions of seed are likely to be removed frequently from the cold storeroom, seeds should be stored in small amounts. Seed can be stored in small sealed plastic bags within a larger container. The volume of air within the container should be low compared to the volume of seeds in the container. If the amount of air is large, the seeds will absorb a lot of moisture from the fresh air each time the seed container is opened. Place substances that absorb moisture such as roasted rice husks, newspapers, charcoal, or silica gel in the container as the volume of seed decreases.

Note that seeds with a high oil content have a lower moisture content than seeds with a low oil content and high protein or starch contents.

Figure 10.6 Seed storage in a cold room at ICRAF



Information compiled by:

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Chapter 11:

Seed Dormancy and Pre-sowing Treatments

Summary

11.1 What is tree seed dormancy?

- A state in which viable seed fails to germinate when provided with conditions that are favourable for germination, for instance, adequate moisture, appropriate temperature, a normal atmosphere and in some cases, light.
- A constraint which prevents the full realization of the growth potential of the seed's embryo under conditions that are favourable for germination of other tree seed species.

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11.2 What is a pre-sowing treatment?

- A pre-sowing treatment is a treatment of seed that enhances its rapid and uniform germination.
- Pre-sowing treatments are most often applied to overcome seed dormancy and accelerate germination.

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11.3 Why should I carry out pre-sowing treatments?

- To enhance rapid and uniform germination of seed.
- To speed up seed germination.
- To safeguard high-quality and expensive seed.
- To use planting space efficiently.
- To be able to predict and concentrate planting and transplanting periods.

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11.4 How do I carry out pre-sowing treatments?

You can accelerate seed germination by carrying out pre-sowing treatments. The best method to use depends on the species that you want to plant.

Common pre-sowing treatments include:

- Soaking in cold water.
- Soaking in hot water.
- Alternate soaking in water and drying.

- Mechanical methods or scarification: the seed coat is cut, nicked, pierced with a hot wire, chipped, filed, cracked, dented or burned so that it becomes permeable to water.
- Heating or burning.
- Acid treatment with such concentrated acids as sulphuric acid.
- Soaking seeds in salt solutions like potassium nitrate.
- Biological treatment: these methods are often based on ingestion by large animals or the effect of insects or microbes.

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Introduction

Seed germination requires suitable levels of moisture, oxygen, temperature and light. If one or more of these are unfavourable, the seeds will not germinate, but if they are favourable, seeds will normally germinate immediately. However, some seeds will show no or little germination although all environmental conditions are adequate and the seed is viable. This situation is described as dormancy, and needs to be overcome before germination can occur. A treatment that breaks dormancy or accelerates seed germination is referred to as a pre-sowing treatment.

11.1 What is tree seed dormancy?

Dormancy is a physiological state that prevents growth in most seeds, even when there appear to be the conditions necessary for germination (such as adequate moisture, appropriate temperature, etc.). Dormancy protects the seed from germinating at the wrong time. For example, it may have a hard seed coat that is impermeable to water and needs to be soaked for many hours before it softens enough to let water through and the seed to germinate. This would protect the seed from germinating straight after the first light rainfall, rather than once the rains have arrived properly, as not until the rains had soaked the ground properly would the seed coat soften enough for the seed to germinate. If the seed did germinate after the first rainfall the chances are that it would then be dry afterwards and the new seedling would die from lack of water.

There are many types of dormancy but they are all based on this basic principle of preventing the seed from germinating until some kind of trigger signals that the optimum conditions for germination are present. They can be categorized as seed coat dormancy, embryo dormancy or a combination of the two – double dormancy. These are explained in more detail below.

When seed is collected before it has reached full maturity it is also not ready to germinate, but this is not classified as dormancy. The seeds simply need to ripen.

Seed coat dormancy

This is also referred to as exogenous (external) dormancy. The embryo is contained within an enclosing structure, which prevents its germination. The enclosing structure could either be the endocarp (the inner layer of the pericarp, for example, the hard, bony part of drupe fruits like neem, teak and gmelina) or the entire pericarp (the wall of a ripened ovary like a fruit wall).

Seed coat dormancies can be subdivided into:

- *Mechanical dormancy*: The development of the embryo is restricted due to a hard seed/fruit coat.
- *Physical dormancy*: Entrance of moisture is impeded because of an impermeable seed/fruit coat.
- *Chemical dormancy*: Fruit and seed contain inhibitory chemical compounds that prevent germination.

Embryo dormancy

This form of dormancy is also called endogenous (internal) dormancy, and is directly related to the embryo.

Different types of embryo dormancy are:

- *Morphological dormancy*: The embryo is not fully developed and needs to grow to full size through ripening, promoted by warmth and moisture.
- *Physiological dormancy*: Certain biochemical components need to be activated before the seed can germinate.

Double dormancy

This is a combination of seed coat and embryo dormancy. It is found in fleshy fruits with chemical inhibitors that are combined with a hard endocarp, for example, *Tectona grandis*.

11.2 What is a pre-sowing treatment?

A pre-sowing treatment enhances the germination of seed. Such treatments are often applied to overcome seed dormancy and used to ensure a uniform germination of seed.

11.3 Why should I carry out a pre-sowing treatment?

- To enhance rapid and uniform seed germination.
- To save high-quality and expensive seed. The treatment ensures the germination of most of the viable seed. When a smaller percentage germinates, more seeds will be needed to reach the target number of trees in the field.
- To ensure efficient use of seedbeds or tubes so that empty places in the seedbed are avoided as much as possible.
- To predict the period of transplanting better, so that proper arrangements can be made.

11.4 How do I carry out pre-sowing treatments?

Find out from available literature or from seed experts the mechanism of determining dormancy and the best pre-sowing treatment for your species. The general method of breaking exogenous and physiological dormancy is to soften or rupture (remove) the seed coat in some way. This can be achieved mechanically or chemically. The better pre-sowing treatments accelerate the natural process so that uniform and prompt germination is achieved. Pre-sowing treatments vary among species. Some methods only require a few minutes, while others require several days. The most common are discussed next.

11.4.1 Soaking in cold or cool water

Soaking in cold or cool water is used to overcome the physical, mechanical or chemical seed dormancy in some species, as shown in figure 11.1. Seed is usually immersed in cold water of about 4 times their volume. The time can vary between 12–48 hours depending on the species. This method can be applied to seeds with a permeable seed coat such as *Crotalaria* spp., *Gmelina arborea*, *Dalbergia* spp., *Sesbania grandiflora* and *Tephrosia vogelii*.

11.4.2 Soaking in hot water

Soaking in hot water is used to overcome the physical dormancy of seeds with hard, thick and waxy seed coats. First boil water of more than four times the seed volume, remove the water from the source of the heat and pour it over the seeds in another pot as shown in figure 11.2. Leave the seeds in the hot water for 6–24 hours. **Do not boil the seeds, as this will kill them.**

Figure 11.1 *Tephrosia vogelii* is soaked in cold water as a pre-sowing treatment



Figure 11.2 Soaking *Tamarindus indica* seeds in hot water



This method can be applied to the seed of *Calliandra calothyrsus*, *Tamarindus indica*, *Sesbania sesban*, *Acacia mangium*, *Leucaena trichandra*, *Leucaena diversifolia* and *Tephrosia* spp.

11.4.3 Mechanical or scarification methods

These methods are used to overcome the physical and mechanical dormancy of species with hard and thick seed coats or fruit shells.

Manual scarification is done by nicking (figure 11.3), piercing, chipping or filing (figure 11.4), cracking (figure 11.5), dewinging (figure 11.6) or burning the seed. A knife, needle, file, hot wire, burner, abrasive paper or secateurs can be

Figure 11.3 Nicking *Calliandra calothyrsus* as a pre-sowing treatment



See also video clip on nicking. ☺

Figure 11.4 Filing *Sclerocarya birrea*



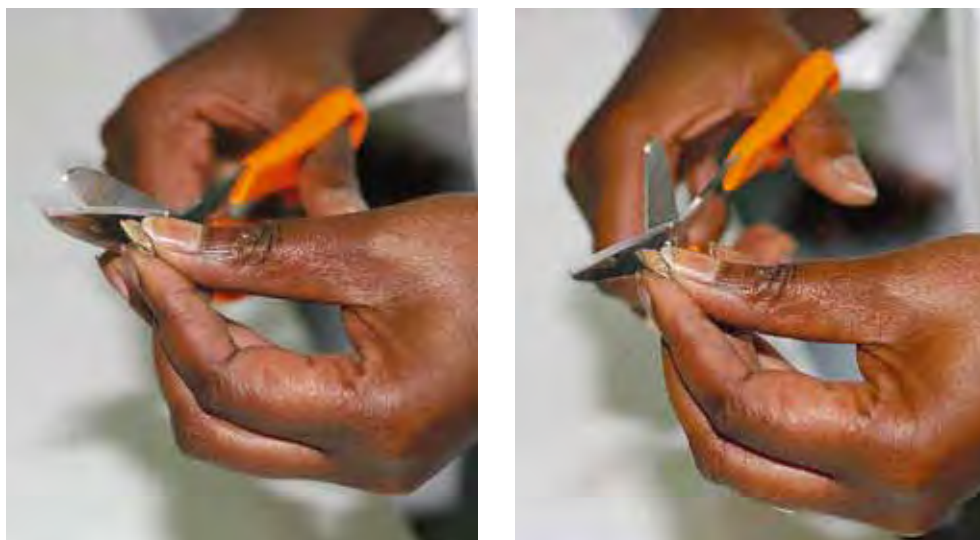
See also video clip on filing. ☺

Figure 11.5 Cracking *Melia volkensii*



See also video clip on cracking. ☺

Figure 11.6 Dewinging *Tipuana tipu*



used. Manual scarification is only applied to small quantities of seed due to high labour requirements. When seeds have wings, the decision on whether to remove the wings before storage (see chapter 9) or not depends on the species. In some species, de-winging is a pre-sowing treatment that makes the seed more permeable to water and should only be applied before sowing and not before storage. Consult seed literature or an expert to find out the appropriate de-winging timing for your species.

Scarification can be done by machine where larger quantities of seed are required. One method involves tumbling the seeds in a concrete mixer with gravel or sand.

11.4.4 Heating or burning methods

These methods are used to overcome mechanical dormancy of seeds with thick shells in either of the following ways:

- Seeds are spread evenly on the ground and covered with a 3 cm thick layer of dry grass or straw. The grass or straw is then set on fire. As soon as the grass is burned, the seed is poured into cold water.
- Seeds are sown in the seedbed, but only half-covered with soil. A layer of dry grass is spread over the seedbed and set on fire. After burning, the seedbed is immediately sprinkled with water. Then the seeds are pushed 2 cm into the soil and watered thoroughly.

11.4.5 Acid pre-treatment methods

These methods overcome mechanical or physical seed coat dormancy by using concentrated acids or other strong chemicals, for example, sulphuric acid, nitric acid, potassium nitrate or hydrogen peroxide. **Be careful when you use such chemicals.**

Seed is soaked in the chemical substance for 5–60 minutes, depending on the species, condition of the seed and temperature of the liquid.

A container that will not be corroded should be used. Good ones are made of glass or thick plastic. After removing the seeds from the chemical they should be washed promptly and thoroughly in cool running water for 5–10 minutes. All traces of chemical should be removed. Seeds should then be soaked in cool water for 24 hours. The washed seeds should be dried unless they are to be sown immediately. The chemical breaks down the seed coat. This method works for such species as *Acacia nilotica*, *Acacia mangium*, *Albizia lebbek*, *Delonix regia*, *Prosopis chilensis*, *Leucaena leucocephala* and *Tamarindus indica*.

Seeds removed from cold-storage rooms or fridges before treatment should be left in their closed containers until they are at room temperature, otherwise moisture will condense on the seed surface and react with the chemical.

11.4.6 Biological pre-treatment methods

These pre-sowing treatments include ingestion by large animals and the effects of insects and microbes. Such methods frequently result in improved permeability of seed. For example, seed from ingested drupes of *Melia volkensii* often germinate well.

Information compiled by:

Anne Mbora

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Chapter 12:

Seed Quality – Physiological and Genetic

Summary

12.1 What is tree seed quality?

- Tree seed quality is a measure of the potential performance of trees when their seed is planted under optimal conditions.
- Quality is determined by the genetic composition of the seed, physiological and physical conditions.

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12.2 What affects seed quality?

- Genetic quality is determined by the seed genotype.
- Physical quality depends on seed size, colour, age, vigour, seed coat condition, and pest or disease damage.
- Physiological quality depends on seed maturity, moisture content or germination ability.

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12.3 How do I ensure that seed is of good quality?

- Ensure proper seed handling and use seed that is clean and free from pests and diseases.
- Use seed that is well documented.
- Carry out tests to check physiological quality.

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12.4 How do I ensure that seed is of good genetic quality?

- Make sure that the seed has high genetic diversity, obtained by collecting from more than 30 mother trees that are not closely related, but occur at distances of 50–100 m from them (see question 8.7), and by collecting equal amounts from trees.
- Collect enough seed to compensate for losses before planting. If you lose many seeds, you may lose a lot of genetic diversity.
- If you do not collect yourself, check the seed documentation. If possible, only buy from a seed dealer with a high reputation.

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12.5 How do I ensure that farmers appreciate physiological quality?

Explain to farmers the value or benefit of good seed, for example, high germination ability, ease of storage, and uniform germination in the nursery.

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12.6 Why should I test the physiological quality of seed?

- To check the value of seed for distribution, sale or planting.
- To maintain seed quality during handling.
- To calculate how many seeds you need in order to obtain the number of trees that you want in the field.

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12.7 What is involved in tree seed testing?

Physiological quality can be determined by seed tests; these include purity, moisture content and germination percentages.

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12.8 What is seed health and why is it important?

- The health of seed refers primarily to the absence of disease-causing organisms such as fungi, bacteria or viruses. It also refers to the absence of pests such as nematodes and insects.
- Physiological conditions such as element deficiency may be involved in seed health.
- Diseases in seed may progress into diseases of the adult tree that reduce its commercial value. The poor health of seeds may also result in poor germination in the field.
- You will gain information on the value of the seed.
- You will be able to meet quarantine requirements for international movement of germplasm (seed or seedlings).
- You do not want to distribute pests and diseases.

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Introduction

Seed quality refers to the value of the seed. Seed that has been handled in different ways may look the same, but may not have the same value. Seed of the best quality results in trees of the best quality in the field. The quality of seed is therefore important to all actors involved in the tree seed system.

12.1 What is tree seed quality?

Tree seed quality is a measure of the potential performance of seed under optimal conditions. Seed of the highest quality will result in trees of the highest value in the field. Seed of low quality will result in trees of poor quality. ‘Good seed doesn’t cost, it pays.’

12.2 What affects seed quality?

Many factors influence the quality of seed and the quality of the trees that will grow from that seed. These factors are categorized as:

- **Genetic quality:** Genetic quality is determined by the genetic information contained in the seed. All the genetic information of the future plant is contained in the genes of its seed. A tree with poor genetic composition will not grow well in the field.
- **Physical quality:** These are characteristics of the seed such as size, colour, age, vigour, and seed coat condition such as absence of cracks, damage and pests and diseases.
- **Physiological quality:** These characteristics directly influence the difference between the number of seeds and the number of trees that will grow from these seeds. They include seed purity, moisture content, germination percentage and vigour. Physiological quality can be measured by seed testing. When the physiological quality is known, the number of seeds needed to obtain the required number of trees in the field can be calculated.

12.3 How do I ensure that seed is of good quality?

Seed can only be of good quality if all the procedures from collection to planting it are properly followed. Otherwise, you will not have collected seed of good quality, or you will have lost much of the quality of the seed.

You can be most certain of the physiological quality of seed by doing the procedures yourself. The previous chapters provide information on the proper procedures that lead to seed of good quality.

If you do not collect the seed yourself, then you need to check the seed documentation to verify whether it is of good quality. A supplier must provide good

documentation of seed quality. If the supplier is not able to do so, it is most likely that the seed is of poor quality. For the same reason, if you supply seed, you should provide good documentation so that your customers can verify the quality of the seed. You can carry out tests to determine the physiological quality of seed.

12.4 How do I ensure that seed is of good genetic quality?

Seed that has low genetic diversity will often grow poorly in the field. However, it is possible that seed of low genetic diversity will perform well (or even better!) in the field, especially if you selected good mother trees.

The reason for needing high genetic diversity is that the environment of trees may change, e.g., by the occurrence of a new pest. The greater variety of genes you have, the more likely that some genes will be suitable for changed conditions. Since genetic diversity only increases slowly through different generations of offspring, ensuring genetic diversity is especially important when you establish a seed production unit.

You can be most sure of the genetic quality of seed by collecting it yourself. Otherwise, you need to check the seed documentation (see chapter 14) to verify the methods by which the seed was collected. You can be more certain about genetic quality by buying seed from dealers with a good reputation. **Do not always choose the dealer that provides the cheapest seed.**

12.5 How do I ensure that farmers appreciate physiological quality?

You could explain to farmers that good seed will be of high value because of its ability to germinate well and uniformly, easy storage, high purity percentage, and absence of pests or diseases. In all cases, the difference in price between good and bad seed will be much smaller than the difference in the value of the end products of good and bad trees.

As part of your explanation, you could point to the natural variation that occurs among trees – some will perform poorly and others much better. Some trees will not perform at all as their seed will fail to germinate. You could also point to analogues of crop breeding, or animal breeding as most farmers have experience with high-yielding varieties or pedigree breeds. Populations with a small number of individuals frequently show a high degree of inbreeding.

Several researchers have pointed out that crops derived from self-fertilization frequently show a high rate of non-viable or hollow seed. Decreases in yields have also been observed in their offspring.

When discussing genetic quality with farmers, point out that inbreeding is bad for human beings, animals and also trees, and that inbreeding in trees is the result of pollination between individual trees that are too closely related.

12.6 Why should I test the physiological quality of seeds?

The main reason for testing seeds is to maintain seed quality during handling, and to know how much seed is required for planting. When seed physiological quality deteriorates faster than you expected, then you can intervene in the way that seed is stored or handled. Seed testing can also be done to determine the value of seed before you buy or sell it.

12.7 What is involved in tree seed testing?

Seed testing comprises procedures that determine various aspects of the seed including: physiological qualities like purity, viability, germination ability and moisture content. Seed tests are not done on all the seeds but on a sample of them. Some tests will destroy the seeds, so you need to consider seed testing when calculating the number of seed that you want to collect.

Seed tests are categorized into **simple tests**, carried out in the field; **standard tests**, carried out mostly in a laboratory that follows International Seed Testing Association (ISTA) requirements; and **special tests**. The simple and special tests results are used as a guide during seed handling, for example, to determine the necessity for further seed drying or to determine whether or not to proceed with seed collection or distribution.

Seed testing is only an **assurance** of good quality. To carry out basic tests of purity, seed weight, moisture content and viability or germination analysis, roughly 2500–5000 seeds are needed, depending on seed size. However, for species with large-sized seeds, reduction of sample size to a minimum of 500 is acceptable. Table 12.1 shows the tests that are done on seeds during the various stages of seed handling.

12.7.1 Seed purity

Since all other seed tests should be conducted on pure seeds, the purity of the seed lot must be determined first.

Samples should be uniform and representative of the entire seed lot. It is better to take a sample from several parts of the container – from the top, middle and bottom of each bag or seed lot using a spear or your hand – to form a good sample. Figure 12.1 shows how a sleeve type trier can be used to obtain random samples from different parts of a container.

Table 12.1 Seed testing during the period of seed handling

	Harvest	Processing	Before storage	During storage
Simple tests	Health (cutting test) Moisture content (moisture meter)	Health (cutting test) Moisture content (moisture meter) Purity (screening)		
Standard tests		Seed weight Purity Moisture content (oven method) Viability/germination (TTZ*, X-ray, germination etc)		Moisture content (oven method) Viability/germination
Special tests			Health test (vigour)	Health test (vigour)/ check disease infection

**Tetrazolium test.*

During the test, the sample is separated into two components: pure seeds and impurities.

The seed purity percentage is the percentage of the weight of pure seeds within the sample. You need to weigh the sample first, then the impurities and and subsequently weigh the pure seed. The seed purity percentage is calculated by following formula:

$$\text{Purity (\%)} = \frac{\text{Weight of pure seed (g)}}{\text{Total weight of original sample (g)}} \times 100\%$$

Figure 12.1 Seed sampling for purity analysis using a sleeve type trier



12.7.2 Seed germination and viability tests

Seed germination or seed viability tests indicate the germination ability (potential germination) of seed. Germination of a representative sample will indicate how many seeds can be expected to germinate in the nursery when the seed is handled properly.

A germination test can be done in a laboratory or in a tree nursery. The germination medium should be non-toxic to germinating seedlings. The containers should be kept free from fungi or other micro-organisms. Other tools useful for germination testing are a magnifying glass, secateurs, and a balance.

Steps for the germination test

1. Randomly pick 400 seeds from the seed lot.
2. Apply the appropriate pre-sowing treatment (see chapter 11).
3. Sow the seed in trays containing a good germination medium as shown in figures 12.2 and 12.3.
4. Keep the medium moist.
5. Count the number of germinated seeds each day, especially, for species that germinate rapidly. Remove germinates as you count them to facilitate subsequent counting and to avoid possible fungal spread. Some seeds require 3–4 weeks to achieve complete germination. The test should be continued until no additional seeds germinate.
6. Calculate the percentage of germination as follows:

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds tested}} \times 100$$

Viability tests are applied to species that are difficult to germinate. These tests can also be used when results are needed quickly to determine the percentage of seed that is alive. Seed that is alive doesn't always germinate

Figure 12.2 Testing germination of *Calliandra calothyrsus* in trays of soil in the nursery



Figure 12.3 Testing germination of *Tephrosia* seeds in trays of sand in a laboratory



however, so the results of the viability test could indicate a higher percentage than those of the germination test.

The most important viability test is the tetrazolium (TTZ) test. The chemical used stains living tissue red. Depending on the amount and location of the stain, you can decide if the embryo is likely to be viable or not.

12.7.3 Moisture content

This test determines the percentage of moisture contained in the seed. The test can be used to determine whether seed is stored under proper conditions or when it is dry enough to be stored.

The moisture content is determined by comparing the seed weight before drying with the seed weight after drying. The moisture that has evaporated causes the difference in weight.

The most accurate way to measure moisture content is by oven drying samples drawn from the working sample in an oven for 17 hours at 103°C (ISTA rules 1976) (see figure 12.4). Seeds are ground or cut into small pieces so that all moisture can escape when the material is dried.

To determine the moisture content you need to obtain three weights: W1, W2 and W3) by following the procedure below (you need to do at least 3 replications of this procedure too in order to get a reliable average):

1. Weigh an empty heat-resistant container together with its cover (W1).
2. Place the ground seeds into the container, cover the container and weigh it again (W2).
3. Place the covered container with the ground seeds in the oven at 103°C for 17 hours.
4. Remove the container from the oven and place it in a desiccation or drying chamber while cooling. This is to prevent the seeds from reabsorbing moisture from the air.

Figure 12.4 Measuring moisture content using a low constant-temperature oven



5. After cooling, weigh the container for the third time (W3).
6. When you have determined W1, W2 and W3, you can calculate the moisture content by using the following formula:

$$\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} \times 100$$

There are faster methods that can be used. These are not so accurate as the above method and thus do not meet the ISTA requirements; but they can be used as a guide during seed handling.

One is to cut the seeds into small pieces before drying in a microwave oven for 5 to 6 minutes. The moisture content is calculated using the same method as above, it is only the drying process that is faster.

Another way to determine seed moisture content is to use an electric moisture meter, which is set at 130°C and heated for 2.5 hours. Using this method you can determine the moisture content without destroying the seed.

Another method which is used for determining moisture content in the field is by using portable moisture meters (see figure 12.5). The moisture meters, need to be calibrated in a laboratory before they can be reliably used in the field.

Figure 12.5 Portable grain moisture tester



A simple way to determine if the moisture content of most seeds (orthodox and intermediate seeds) is low enough for safe storage is by using the **salt test**. You will need a clean dry jar with a lid, some salt and a sample of the seeds to be tested. Make sure that the jar you use is clean and completely dry. Fill one quarter of the jar with salt and then add the seed, then close the lid tightly and shake the jar well (see figure 12.6). Then allow the seeds to settle for about 10 minutes.

If damp salt sticks on the sides of the jar, the seeds are too moist for storage, meaning that the amount of moisture in the seeds is above 13–15%, the moisture content which is the maximum for storage. If the jar is still dry and no salt is stuck on its sides, the seeds have less than 13% moisture content, and can thus be stored safely.

12.7.4 Seed weight test

The seed weight test determines the number of seeds per unit weight. It does not actually determine the physiological quality of seed, but is useful in calculating the amount of seed that you need if you want to plant a certain number of trees.

Figure 12.6 Salt test



The test is conducted by weighing a pure sample of 1000 seeds. If the seed lot is small, 100 or 500 pure seed can be used to determine the weight. To arrive at more accurate numbers, it is better to determine the weight of 4 equal numbered samples and then calculate the average. Figure 12.7 illustrates a seed weight test.

$$\text{Number of seeds/kg} = \frac{1000}{\text{mass of sample (g)}} \times \text{number of seeds in sample}$$

12.8 What is seed health and why is it important?

Seed health refers primarily to the extent to which seed contains disease-causing organisms and pests. Fungi, bacteria or viruses can cause seed diseases; while nematodes and insects are the main pests. Conditions such as element deficiency in the seed can also contribute to poor health.

Testing of seed health is important for various reasons:

- Seed-borne inocula may give rise to progressive disease development in the field and reduce the commercial value of the trees.
- Imported seeds could introduce diseases into new regions.
- To meet quarantine requirements for plant importation.
- Seed health is one of the factors that determine the quality of seed. Unhealthy seed will result in poor trees.
- Information on seed health will help you to calculate the number of seeds that you require to meet your target number of trees in the field.

Figure 12.7 Seed weight determination test samples



Note: the number of seeds per kilogram may differ depending upon the variety, provenance and year.

Information compiled by:

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Chapter 13:

Seed Distribution

Summary

13.1 Where should I distribute my tree seed?

- Distribute seed only to areas that are ecologically similar to the planting area.
- Distribute seed where there is a demand.

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13.2 How should I distribute my tree seed?

- Ensure that seed quality is maintained and that it reaches the user at the right time and in sufficient quantities.
- Carry out seed tests before distribution to determine the potential of the seed (see chapter 12).
- Provide the client with appropriate documentation (see chapter 14).
- For international transfer of seed, observe the restrictions and legislation of the importing country.

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13.3 How should I package my tree seed?

- Use packing materials that are strong enough to resist damage during ordinary handling and that are moisture-proof. Good materials are sealed polythene bags or aluminium bags. Double-lined envelopes are good for small amounts of seed.
- Each pack should have basic documentation both inside and outside (see chapter 14).
- For transport, seeds should be sealed in an inner package and then put in a cardboard or wooden box for transport.

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13.4 What information should be in a dispatch note?

- The dispatch note should contain the seed documentation (see chapter 14).

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13.5 What are seed distribution, dissemination and diffusion?

- Seed distribution is the act of distributing seed to large organizations such as NGOs.
- Seed dissemination is the issue of seed from large organizations to farmers.
- Seed diffusion is the dispersal of seed from farmers to other farmers.

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Introduction

Seed distribution is the act of distributing seed or the process of dispersing seed from seed collectors to users. It involves the exchange of seed between different people. There are many types of seed distribution, for example, farmer-to-farmer exchange, sale by seed vendors, or buying and distribution by NGOs. This chapter describes the best technical methods of tree seed distribution.

13.1 Where should I distribute my tree seed?

Distribute seed into ecological zones that are suitable for the seed that you have collected. In most cases, you can only be sure that a particular species is suitable if you distribute its seed to a zone with similar ecological characteristics to those in the planting area. Such ecological characteristics include altitude, rainfall and temperature (see chapter 6).

To be sure of the ecological suitability of a species, the purchaser of seed has to indicate the ecological conditions of the planting site. The supplier then proceeds to choose seed that matches these conditions.

Distribute seed where there is a demand for it, where the trees are promoted by an organization and where trees are useful to users. Avoid wastage, since seed is costly, and try to maintain its quality until it is distributed.

13.2 How should I distribute my tree seed?

Carry out seed tests before distribution to determine the potential of the seed (see chapter 12), and then plan to supply in sufficient quantities and at the right time. When the time between the arrival of the seed and planting is minimized, less seed is lost due to loss of viability (see chapter 12). Use the following formula to calculate the quantity to send to a client based on the number of trees that the client requires.

$$\text{Quantity of seeds required (kg)} = \frac{\text{Number of seedlings desired}}{\text{Purity (\%)} \times \text{Germination (\%)} \times \text{Number of seeds/kg}}$$

Make sure that quality is maintained from the moment the seed is collected to the time it is distributed.

Avoid wastage by ensuring that seeds will be planted. Wastage can be prevented if a species is being promoted and is useful to the clients (see chapter 6).

Provide the client with sufficient documentation (see chapter 14). You may need to carry out several seed tests (see chapter 12) to be able to provide the client with information on quality.

For international transfer, observe the restrictions and legislation of the importing country. In most countries, a phytosanitary certificate for imported seed is required. The certificate is issued by an accredited authority in the exporting country and states that the seed has been examined and found free from pests and diseases. The certificate will also state whether the seed has been subjected to fumigation or chemicals. An import permit is usually sent from the importing country to the exporting country before the exporting country prepares the phytosanitary certificate.

13.3 How should I package my tree seed?

Use packing materials that are strong enough to resist damage during ordinary handling. The packaging material should be moisture-proof. Suitable materials are polythene or aluminium bags that are securely sealed. Double-lined envelopes that allow air to pass through are good materials for packaging unmanageable seed or small samples of seed for research. The principles of seed storage should also apply in distribution; for example, all orthodox seeds should be sufficiently dried before packaging.

The volume of air around orthodox seeds should be kept to a minimum so that they do not absorb too much moisture from the air (see chapter 10). Use a heat-sealing machine or a candle to seal polythene bags. The containers that are used for storing seed (see chapter 10) can also be used to dispatch seed. However, this may be quite expensive and may only be appropriate for clients who require large volumes of seed.

For shipment, seeds should be packed in inner and outer packages for extra protection. Good outer packages are cardboard or wooden boxes. A copy of the phytosanitary certificate should be put inside the packages. Each pack should also contain basic documentation both inside and outside.

13.4 What information should be in a dispatch note?

The dispatch note should contain the basic documentation of the seed and a copy of the phytosanitary certificate if the seed is for export. A seed dispatch note should include the following information:

- Botanical and local name of species.
- Seed source and provenance.
- Number of parent trees.

- Date of collection.
- Weight.
- Purity (%).
- Viability test results/germination (%).
- Pre-sowing treatment used.

Do not exchange seed alone, but also provide information about it. Quality seed = seed + documentation. ‘Good seed doesn’t cost, it pays’ (see chapter 14).

13.5 What are seed distribution, dissemination and diffusion?

There is a difference between distribution, dissemination and diffusion:

- Seed distribution is the transfer of seed to large organizations such as NGOs.
- Seed dissemination is the transfer of seed from large organizations to farmers.
- Seed diffusion is the transfer of seed from farmers to other farmers.

What will often happen in an area is that seed is transferred firstly by distribution, secondly by dissemination and thirdly by diffusion. A large organization will have more control over the quality of seed during the distribution and dissemination phases, but less control during the diffusion stage. The advantage of the diffusion stage is that a larger volume of seed is transferred, and that this system is more sustainable. The quality of seed needs to be addressed during the diffusion stage, but the critical moment to address quality is in the earlier stages of distribution and dissemination.

Information compiled by:

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Chapter 14:

Seed Documentation

Summary

14.1 Why should I document seed?

- Seed should be documented to give it an identity. You may for instance want to plant more seed of a similar identity at a later stage, or want to conduct an impact assessment of seed distribution activities.
- Documentation allows verification of seed quality (quality assurance) for the client by the producer. Quality seed = seed + documentation.
- Documentation removes the burden of memorizing details during all the stages of seed production and distribution. It also allows for the continuity of activities after changes in staffing.

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14.2 What are the most common documents in seed production?

These include documents on:

- Source.
- Collection and handling.
- Quality test results.
- Storage.
- Dispatch.
- Stand establishment.

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14.3 What other documents are important in seed production?

- Cost of operations.
- List of sources or catalogue.
- Research records and publications.

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Introduction

High-quality seed is closely linked to a good record and documentation system. It is important to note that documentation or record keeping does not make the seed better or poorer, since some undocumented seed can grow well. Documentation does however provide **quality assurance**. This chapter describes the reasons why seed documentation is important, and introduces you to the most common documentation processes used in seed production.

14.1 Why should I document seed?

When you document seed, you give the seed lot an identity. The species, the seed source, the date of collection and the method by which the seed was collected determine the identity of the seed lot. If you give a seed lot a number, it is best to use some meaningful codes that refer to species, origin, and year of collection. For example, Sesses-Kak-99-3 could refer to the third collection of *Sesbania sesban* from Kakamega Forest in 1999.

Seed documentation helps in planning future seed procurement. A client could require more trees from the same source at a later stage. The client needs the proper documentation to be able to make a request for such seed. The seed dealer could also keep a record of the clients and the identities of the seed that was distributed to them in order to accommodate future requests.

The most important reason for documentation is that it enables the client to check the quality of the seed. It also enables the dealer to maintain seed quality.

Proper documentation removes the burden of having to memorize details. It allows for the continuity of activities whenever there are staff changes. **Make sure that you properly archive documentation. Make backups of information to prevent losses due to fire, theft or a computer breakdown.**

14.2 What are the most common documents in seed production?

The documents typically used during the various stages of seed production include the following:

Seed source documents. These contain information on:

- Name of the species (botanical and local names).
- Geographical location of the seed source.
- Geographical location of the original seed source in the case of a seed orchard or seed production unit (see chapter 7).

- Ecology of the seed source (elevation, temperature, rainfall, soil types).
- Ecology of the original seed source in the case of a seed orchard or seed production unit.
- Number of trees in the seed source.
- Age of the seed source.
- Size of the seed source.

See chapter 7 for further details.

Seed collection and handling documents. These contain information on:

- Name of the species (botanical and local names).
- Seed source or provenance (from where the seed was collected).
- Date of collection.
- Number of parent trees from which seed was collected.
- Average distance between seed trees.
- Weight of fruit or seed collected.
- Number of seed containers filled with collected seed.
- Name of collectors.

See chapters 8 and 9 for further details on seed collection and handling.

Seed storage documents. These contain information on:

- Seed lot number (a unique identification code that identifies the seed collected in a specific year from a specific seed source).
- Name of the species (botanical and local names).
- Weight stored.
- Running balance.

See chapter 10 for more information on seed storage.

Seed quality test results. These documents contain information on:

- Seed test number (a unique number that identifies particular results of seed lots. This number is different from the seed lot number).
- Seed lot number (a unique identification code to identify the seed collected on a specific date from a specific seed source).
- Name of the species (botanical and local names).
- Date of seed testing.
- Seed purity percentage.
- 1000-seed weight test or number of seeds per kg.
- Moisture content percentage.
- Germination percentage.
- Cutting test.

See chapter 12 for more information on quality tests.

Seed dispatch documents. These contain information on:

- Name of the species (botanical and local names).
- Weight required.
- Weight issued.
- Seed lot number (a unique identification code to identify the seed collected on a specific date from a specific seed source).
- Date of dispatch.
- Seed test information (purity and germination).
- Seed advice note.
- Dispatch note.
- Number of parent trees.

See chapter 13 for more information on seed dispatch.

Seed labelling documents. These contain information on:

- Botanical and local names of the species.
- Date of collection.
- Seed source or provenance.
- Number of parent trees.
- Seed quantity (kg).
- Purity percentage.
- Viability test result or germination percentage.
- Method of pre-sowing treatment.

See chapter 13 for more information on seed dispatch and seed labelling.

14.3 What other documents are important in seed production?

Other types of information could help you improve future activities and enable proper planning.

One is information on the costs of all operations. For instance, the cost of seed collection could be calculated as fixed costs (costs that will be same for each collection) and variable costs (costs that will be different for each collection). Fixed costs include items like the purchase of a vehicle, climbing equipment and protection gear, and the cost of constructing seed storage and testing facilities. The variable costs in seed collection include fuel, allowances, and raw material for processing and testing seed. Keeping good documentation of costs is very important, as it makes it easier to get an idea of the overall cost of seed collection and handling. This allows you to come up with a fair price for the collected seed and to plan future activities.

Another type of useful documentation is a list of seed sources. This list (or register) could include all the seed sources that have been identified, selected

or established. Such a register would be useful if you wanted to provide your clients with a catalogue of available seed.

Some documentation may refer to experimental records collected from the source. One objective could be to improve seed production in the future. You need to keep records and document accurately so that data can be properly analysed. The documentation may also contain a list of the publications that were prepared at the end of the research activity, or a list of other publications that are relevant to your seed production work.

Information compiled by:

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PART III:

The private sector and seed production

Chapter 15:

The Business Approach

Summary

15.1 What is the business approach?

It is an approach which looks at the market and demand for a product before getting into an enterprise as a source of income. It helps to better plan and operate your business.

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15.2 What is a business plan?

A business plan is basically a blueprint of the enterprise and also a road map for the direction that the enterprise will take.

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15.3 Why should I have a business plan?

A business plan is a tool with four basic purposes: communication, management, planning, and assessing performance.

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15.4 What do I need to make a business plan?

1. Description of the business.
2. Business objectives.
3. Current performance analysis.
4. Marketing strategy/plan.
5. Production plan.
6. Financial plan.

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Introduction

This chapter talks about operating a nursery or seed business from a purely business point of view. The following pages include the basic concept of the business approach; the elements of a business plan, and how to use a business plan to better facilitate nursery and seed operations. It is understood that every nursery or seed supply unit is a business. This chapter and the following chapters help to better understand and run a business. This chapter addresses the basic tenets of a business, indicating how to write a business plan and how to use it to streamline production, assess credit requirements and cash flow and understand the consumers of the product, in order to better serve them.

15.1 What is the business approach?

It is an approach that looks at the market and the demand for a product before getting into an enterprise as a source of income. It follows a for-profit ideology, which means that every activity carried out in the enterprise should attempt to generate higher returns and be beneficial to the business.

The business approach is essentially a way to organize one's enterprise to best use one's strengths and weaknesses in the most profitable manner. The business approach calls for the entrepreneur to be organized, methodical and clinical in operations and information gathering. The best way to understand the business approach is by writing a business plan for one's enterprise.

15.2 What is a business plan?

A business plan is basically a blueprint of the enterprise and also a road map for the direction that the enterprise will take. The business plan should provide evidence of focus, understanding of the target customers, financial requirements of the enterprise and annual plans to realize the goals of the enterprise.

15.3 Why should I have a business plan?

A business plan is a tool with four basic purposes: communication, management, planning and assessing performance.

- **As a communication tool**, it is used to attract investment capital, secure loans, convince employees, and assist in attracting strategic business partners. The development of a comprehensive business plan shows whether or not a business has the potential to make a profit. It requires a realistic

look at almost every phase of business and allows you to show that you have worked out all the problems and decided on potential alternatives before actually launching your business.

- **As a management tool**, the business plan helps you track, monitor and evaluate your progress. The business plan is a living document that you will modify as you gain knowledge and experience. By using your business plan to establish timelines and milestones, you can gauge your progress and compare your projections to actual accomplishments.
- **As a planning tool**, the business plan guides you through the various phases of your business. A thoughtful plan will help identify roadblocks and obstacles so that you can avoid them, and establish alternatives. Many business owners share their business plans with their employees to foster a broader understanding of where the business is going.
- **As a performance tool**, your written business plan is an operating tool which, when properly used, will help you manage your business and work effectively towards its success. Your business plan will allow you to set realistic goals and objectives for your enterprise's performance, and, if maintained, will also provide a basis for evaluating and controlling the company's performance in the future.

A business plan helps you set priorities on things to do, given limited resources.

15.4 What do I need to make a business plan?

1. Description of the business.
2. Business objectives.
3. Current performance analysis.
4. Marketing strategy/plan.
5. Production plan.
6. Financial plan.

15.4.1 What is meant by description of the business?

The business description should include the nature of the business, whether it is retail, wholesale, brokerage or trading house; facts about the enterprise, including size, starting date, employees, turnover and number of customers; and the description of the products sold.

15.4.2 What are the business objectives?

Business objectives are essentially the targets to be achieved. The targets may be sales targets that you want to achieve, the number of customers you want to reach, or the amount of profit you want to make. It is a good idea to establish a time frame in which to achieve these targets.

15.4.3 What is current performance analysis?

Current performance analysis is basically taking stock of the situation. It is an objective self-assessment of your enterprise.

- What is your current share of the market, in terms of volume of sales and population reached?
- What are the market trends, what is selling, what is not selling?
- What are the costs incurred?
- What are the strengths, in terms of what is doing well and why?
- What are the weaknesses, in terms of what is going wrong and why?
- What are the opportunities, in terms of existing possibilities for improvement?
- What threats exist, in terms of what should you should be careful about?

15.4.4 What is a marketing strategy or plan?

The definition of marketing, according to the American Marketing Association, is “the process of planning and executing the conception, pricing, promotion and distribution of ideas, goods, and services to create exchanges that satisfy individual and organizational objectives”.

Marketing is essentially based on two basic principles:

- Activities should be directed towards satisfying customer needs.
- Profitable sales volume is as important as, if not more important than maximum sales volume.

A sound marketing plan is key to the success of your business. It should include your market research, your location, the customer group you have targeted, your competition, positioning, the product or service you are selling, pricing, advertising, and promotion. Effective marketing, planning and promotion begin with current information about the market place. Visit your local market, talk to customers, study the advertising of other businesses in your community, and consult with any relevant government or industry associations.

A marketing strategy could be planned by carrying out some background research in terms of analysis of:

- Consumers.
- Competition.
- Location.
- Market trends.

Consumer analysis

The consumer analysis contains the following information:

- Your current customer base: age, sex, family size, number of earning members in the family.

- Buying or purchasing power: level of income, consistency of income and type of employment.
- Literacy level.
- How they come to your enterprise and transport the product.
- How your customers learn about your product or service. Through advertising, direct mail, word of mouth, pamphlets, radio or posters?
- Patterns or habits your customers and potential customers share; where they shop, what they read, watch and listen to.
- Qualities your customers value most about your product or service; such as selection, convenience, service, reliability, availability and affordability.
- Qualities your customers like least about your product or service – can they be adjusted to serve your customers better?
- Are you offering the kinds of goods or services they want – at the best place, at the best time and in the right amounts?
- Are your prices consistent with what buyers view as the product's value?
- Are your promotional programmes working?
- Factors that limit or influence their demand.

This helps you plan promotional and advertising activities – types of products to keep, quality of products, time of purchase and factors that influence their demand.

Competitive analysis

It is important to carry out an assessment of the competition around you. Which other enterprises sell similar products? This information will help you to plan your marketing strategy. Do you reduce prices compared to those of others? Do you introduce new products that the others don't yet have? What is the competitive edge you need to increase your sales? This analysis can be carried out by addressing the following:

- Who are your five nearest direct competitors?
- Who are your indirect competitors?
- Is their business growing, steady, or declining?
- What can you learn from their operations or from their advertising?
- What are their strengths and weaknesses?
- How does their product or service differ from yours?

Location analysis

The location of your business is very important in terms of marketing. Your location determines the customers you attract, the supply of products to you, visibility of your business and cost factors, in terms of transport. The questions to ask are:

- Are you close to a good access road?
- Are you located in a community market?

- Are you close to your strongest competitor?
- What is the profile of the people who live around your business site?
- Are your suppliers located near by?
- What commercial activities are carried out in the area?
- What kind of access to infrastructure exists in the area?
- What are the local government policies?

Market trend analysis

The market trend analysis helps you understand your industry. It mostly involves secondary data analysis of government sources, market information agencies, chambers of commerce, industry federations, market research company databases and company balance sheets and sales data. The questions to be asked are:

- Is the industry growing or shrinking?
- Are more enterprises or businesses entering the market?
- Are sales going up or down?
- Are there any new products in the market?
- Is there any new government policy (fiscal or monetary) that has been introduced for the sector?
- What trade barriers do you have to overcome (for instance quality and trade zones)?
- Are prices going up or down?

The above four analyses should be used to do the following:

- Define your business plan for the next time period.
- Forecast market demand in terms of what can be sold, who it can be sold to, how much can be sold.
- Price the product.
- Come up with a workable promotional strategy.
- Target a specific type of customer.
- Understand product quality and quantity requirements.
- Understand seasonality of demand.
- Look at product diversification to hedge risks and/or increase profits.
- Plan resource requirements based on perceived market demand.
- Define a competitive edge that is unique to your business.

The four Ps of marketing need to be understood based on the information gathered: product, price, promotion and placement.

Product (and services)

Product strategies may include:

- Concentrating on a narrow product line.
- Developing a highly specialized product or service.
- Providing a product–service package containing unusually high-quality service.
- Branding the product.

Price

The right price is important for maximizing total revenue. Generally, higher prices mean lower volumes and *vice-versa*; however, small businesses can often command higher prices because of their personalized service.

Promotion

Promotional strategies include advertising and direct customer interaction. Good sales ability is essential for small businesses because of their limited ability to spend on advertising. There are many ways to promote a business.

- Good presentation of the products and the area of business.
- Pamphlets and posters at central locations.
- Free samples of products.
- Advertising in the local newspaper, radio or telephone directory.
- Additional services like home delivery or longer business hours.
- Schemes like ‘buy one get one free’, or ‘a chocolate with every two products bought’.
- Discounts on special occasions or during off-season times.

Placement (sales and distribution)

The placement of the business defines the sales and distribution of the products. It also influences costs.

- Locating a business in low traffic, low population areas means higher advertising and distribution costs, higher prices and, maybe, lower sales.
- Locating a business in an area with no competition, even if it is a low traffic area, means you can be a price maker, not a price taker, and any demand the area might have will be met only by you.
- Locating a business in an area with lots of competitors means that you are going to have to follow market trends, become a price taker, have access to a small part of the market, spend on promotion, or reduce the price of your products to increase your market share.

15.4.5 What is a production plan?

A production plan is basically a supply chain analysis of the product. The marketing strategy or plan tells you the type, quantity and quality of products to keep. A supply chain contains all the elements of the resources required for the business. It includes the basic product being sold, the production material required, the logistics required to establish supply of the raw material for production, and the time required for the production process. The production plan is based on the market strategy and helps you understand the following:

- What raw materials are required.
- Where to get the raw materials.
- Time taken for the raw materials to be collected or supplied.
- Who your suppliers are.
- How much time it will take to produce the finished goods.
- What resources are needed for production.
- How much of the finished product can be produced at a time.
- How much the resources will cost you.
- How often the raw material is required.
- How seasonality affects your procurement of raw material and the production process.

A strong supply chain is very important to establishing a good business. A strong supply chain allows the entrepreneur to:

- Keep good inventory control.
- Feed the demand of a product.
- Get a new product for which demand is perceived.
- Ensure that there is enough supply of products to meet the market demand.

15.4.6 What is a financial plan?

A financial plan is an assessment of financial requirements for the planning period. It is important to know the following:

- Size of costs to be incurred.
- Types of costs, including raw material costs, labour, transport, infrastructure and taxes.
- When the costs will arise.
- What the mode of payment will be.
- Current savings.
- Expected exchange rate fluctuations (in the case of overseas trade).

Based on the current performance analysis and expected demand in the time period planned for, a sound financial plan lends stability to the business.

It helps in:

- Assessing credit needs for the planned period.
- Pricing of the product.
- Planning expansion and diversification.
- Executing the business plan.

Costing of the product is of primary importance, since the profit margins are usually calculated as a percentage of costs incurred. It is important to factor in all the costs incurred in manufacturing and buying the product.

Costs include:

- Raw material.
- Transport.
- Labour.
- Infrastructure.
- Taxes incurred or to be incurred.
- Profit margins.

The costing exercise analyses the costs incurred in the production of the finished goods. Many small businesses make a loss without actually realizing it, since they do not carry out a costing exercise.

Information compiled by:

Anand T Aithal

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Chapter 16:

Marketing Seed and Seedlings

Summary

16.1 How do I assess seed and seedling demand?

The demand for a particular tree species changes over time. Not every client has the same needs, and therefore not every tree species will be required by every client. To assess current and future seed and seedling demands, you need to set up a market information system, which includes basic market research, and sales and customer records.

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16.2 How do I find markets for tree seed and seedlings?

You need to know your target group, so that you can judge whether you could reach new customers. You can judge what customers want by listing your current customers and noting what they buy. Find out whether you could sell your seed and seedlings at places other than where you currently sell. You can increase your business by providing new products (new species), or by providing your products at new markets. Check whether your current customers need new products, and where other products are marketed.

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16.3 How much should I charge for seed or seedlings?

First, you need to find out how much it costs to collect seed or produce seedlings, and then find out how much a customer is willing to invest. From the cost of production and the desired profitability levels you will work out a reasonable price for your seed or seedlings. Remember that customers will return when you provide good-quality seed or seedlings at a reasonable price, do not provide low-quality seed or seedlings or overcharge.

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16.4 Which species will give the nursery the highest profits?

You need to assess the demand levels for each species that you stock. Some species are demanded in small quantities, while others are demanded in large quantities. The species demanded in small quantities may, however, sell at high

prices, and therefore have a high profit margin. Species that are demanded in large quantities have low profit margins per unit, but the high volume of demand compensates for overall profit margins.

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16.5 How should I package my seed or seedlings?

Try to estimate the average quantities of seed or seedlings that your customers require. Make a calculation of the costs involved in producing a packet of a certain size of a certain species, so that you can determine your profit margin. Label the packets well since this indicates the quantity and quality of the seed or seedlings. For seedlings of species that are required in small quantities but fetch a high price, you could make the seedlings more attractive by packing them in big containers. For species that are sold in large quantities, do not invest a lot in packaging since the returns are low.

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16.6 How should I advertise my business, especially for new species?

You should advertise to attract more customers. Provide customers with your contact details if you do not permanently sell from the same place. Your customers will direct other customers to you and you will appear to be more trustworthy. Use sign boards to increase the visibility of your nursery from the road. Your visibility will increase further if you make yourself known to extension officers and NGOs, or when you join an association. For new species, you need to compile information on the benefits of the species, and how long it will take for farmers to receive these benefits. When customers get this information, they will perceive the new species as better than existing species, and raise that particular species' demand. You could increase this demand by initially supplying small quantities of the species before demand builds.

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16.7 How do I make sure that customers return?

Satisfied customers will always return. You need to supply the right species, right quality, right quantity, right price and extra services that are needed. Adding extras such as new species or good information on end products may further impress your customers. When you sell seed, you may need to explain seed germination methods, answer every question that customers have and solve any problems together.

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16.8 How should I interact with my competitors?

Do not consider other seed dealers or nursery operators as dangerous competitors, since such an attitude may result in lowering prices to unsustainable levels or selling poor-quality seed or seedlings. One nursery operator may have some species that your customers want but that you lack, whereas the operator may need some of the species that you have in excess. Working as a group of dealers may also result in reasonable prices that will ensure more profit, exchange of market intelligence and access to more seed sources, thus increasing business for all.

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Introduction

Seed supply to farmers by government forest and agricultural ministries has reduced over time and is no longer reliable. Private seed companies have managed to handle the supply of agricultural crop seed and reach the majority of farmers. Whilst tree seed has mainly been supplied by NTSCs whose sustainability and ability to handle all seed demand is not assured (see chapter 1), private individuals and groups have often supplied tree seed and seedlings to farmers in informal settings. This should be encouraged and, in order to be more effective, dealers should supply according to farmers' needs, and to make profits so their business is sustainable. Marketing skills are thus very important as part of a good business approach. This chapter introduces some marketing methods for seed and seedlings that may help to make a seed or seedlings business profitable and sustainable.

16.1 How do I assess seed and seedling demand?

There is a belief that there are some species that farmers will just keep buying. This is not the case, since demand shifts over time and between customers. This is why we need a market information system (MIS). A seed and seedlings MIS should start with simple market research that can be conducted through either an informal survey or observation. The survey should involve farmers and farmers' groups, nursery operators, schools, NGOs and extension agents. Once the business is in place, demand can be progressively assessed by keeping good records of sale, customers and prices. Analyse these records to find out which species have the highest or lowest demand, the demand trend over the recent past and to make speculations of future demand. Networking with other seed dealers and nursery operators can also help you determine new demand trends.

16.2 How do I find markets for tree seed and seedlings?

You need to know your target client group. It is possible to reach more existing customers or new customers. You can maximize the number of farmers that you reach by listing your current customers and noting which species they mostly buy, for what purpose and when. Is it advantageous to concentrate on one group of customers and increase your market share of that group? You also need to know the potential market, for instance, if you are not selling at any big markets, could you do so without incurring too much extra cost? Talk with other seed and seedling dealers, because you may find it helpful to collaborate as a group. Try to make contacts with seed and seedling dealers further away, near big cities for example, where there may be opportunities for you to supply them. Also look at what services you can offer: examine the

whole chain from seed supply to harvesting the tree product. How can you increase your share of that whole chain?

A simple version of the entrepreneur’s window is shown in table 16.1. As a seed dealer or nursery operator, you need to consider your current *status quo*. What species are you currently selling and who are your customers? That is the top-left box in the window. Since you already have the capacity to produce and supply the seed or seedlings, you will only have to increase the number produced if you find existing gaps in supply.

Then look at the potential markets that have not yet been exploited. These include schools, private farms, ranches, prisons, towns and fruit or grain markets near you. You might benefit from keeping close contact with the forest or agricultural extension officers for the area so that they pass on any enquiries that come their way. In this case, you are addressing the top-right box of the window.

You also need to analyse your current customers and see if you are supplying everything they need. Is there a demand for other species that you are not supplying? Could you also supply other accompanying products such as compost or polythene bags if you are selling seed to nursery operators? Could you also offer tree planting services if you are selling seedlings to schools, airports etc.? This addresses the bottom-left box of the entrepreneur’s window. You could also target both approaches and enter new markets inclusive of new products (bottom-right window).

16.3 How much should I charge for seed or seedlings?

The price of seed or seedlings is determined by what farmers or other users perceive as the value of the species or variety. Market principles of supply and demand should define the price of a seedling, but the problem is that the market is not often perfect and there are distortions. For example, the supply of free seed and/or subsidized seedlings by projects lowers the price. As mentioned in chapter 17, seedlings are often not sold with profit in mind. By starting to look at the costs of production and desired profitability levels,

Table 16.1 The entrepreneur’s window

Current products	Current products
Existing markets	New markets
New products	New products
Existing markets	New markets

nursery operators and seed dealers can work out the minimum price at which to sell their seed and seedlings. You can increase your gross margin (profitability) through efficient management and effective marketing. Table 16.2 illustrates gross margin analysis techniques.

At a workshop conducted outside Nairobi, in Kenya, nursery operators compared the prices they charged for different products. One group presented a gross margin analysis (see example calculation below) on an ornamental plant (Bird of Paradise flower). They were making a very large margin because their volumes were not high. The price they charged for one plant was Ksh 250 (US\$ 3.5). An operator from Athi River was very surprised to realize this, since he only charged Ksh 50 (US\$ 0.7) for a plant. He therefore decided to raise his prices.

Using the gross margin analysis techniques, you can work out how much it costs to produce a quality seedling. The cost includes variable costs and fixed costs like water and depreciation of your tools and machinery. You can see from table 16.2 that it costs Ksh 2.0 to produce one seedling. Since not all seedlings were valued (some seedlings dried), the gross margin per seedling was Ksh 2.83 $[(2,300 - 1,000)/460]$. You can check from the table that the unit price of each seedling valued (Ksh 5.0) can be split into cost per seedling produced (Ksh 2.17) and the gross margin per seedling (Ksh 2.83). For the table calculations, other values were included – seedlings planted on own farm, seedlings given away, and seedlings not sold – thus the Ksh 5.0 unit price. If the gross margin analysis were to focus on cash income from the nursery alone, only seedlings that are sold would be valued.

Farmers will only be willing to pay a certain amount for a quality seedling, so you will need an assessment of how much to invest in quality and still make a profit. Remember that quality products ensure that the customer is satisfied and will return. Customers are also likely to return when you do not overcharge them. However, note that the number of seedlings given away or planted on your own farm and those in the remaining stock all contribute to gross margin. The objective should be to ensure that most of the produced seed or seedlings are sold. By carefully assessing demand, you will not have a lot of unsold stock to lower your revenue.

16.4 Which species will give the nursery the highest profits?

Using the gross margin techniques combined with market information, you can work out the profit margin on one unit (1 kg seed or 1 seedling) of a species, and determine the quantities to stock. This will differ by species and provenance depending on demand and customers' knowledge and appreciation of the species. As a general guideline, the profit you are likely to make should be between 20% and 50% of the production cost per unit.

Table 16.2 Hypothetical gross margin calculation for *Grevillea robusta*

Item	Unit	Quantity	Unit price	Value
Total production	seedlings	$s = 500$	5	–
Total maximum income	seedlings	500	5	2,500
Gross income				1,800
• Value of amount sold	seedlings	360	5	275
• Value of amount planted on own farm	seedlings	55	5	100
• Value of amount given away	seedlings	20	5	125
• Value of dried seedlings	seedlings	25	5	0
• Total gross income	seedlings	40	0	$i = 2,300$
Variable costs				
• Seeds	kg	0.25	1,000	250
• Polytubes	pack of 100	5	30	150
• Hired labour to fill polytubes	person day	1	80	80
• Sand	wheelbarrow	1	50	50
• Manure	wheelbarrow	1	50	50
• Soil	wheelbarrow	2	50	100
• Total variable costs	–	–	–	$vc = 680$
Fixed costs	–	–	–	$fc = 320$
Total costs	–	–	–	$c = vc + fc = 1,000$
Total gross margin	–	–	–	$g = i - c = 1,300$
Cost per seedling produced	–	–	$c/s = 2.0$	–
Gross margin per seedling produced	–	–	$g/s = 2.6$	–
Number of seedlings valued	–	$v = 460$	–	–
Cost per seedling valued	–	–	$c/v = 2.17$	–
Gross margin per seedling valued	–	–	$g/v = 2.83$	–

$m =$ Quantity produced; $s =$ Quantity sold; $i =$ Total gross income; $g =$ Total gross margin; $c =$ Total costs; $vc =$ Total variable costs; $fc =$ Fixed costs; $c/m =$ Cost per seedling produced; $c/s =$ Cost per seedling sold; $g/s =$ Gross margin per seedling sold

Note: Average production cycle is 3 months

Depending on the market segment, some species are required in low quantities but sell at high prices, for example, indigenous species or grafted fruit species in Nairobi. For these species, you can have high profit margins even though the total production cost is low. You need to assess the demand levels for such species in order not to overproduce them.

On the other hand, some species have low prices, leading to low margins per unit, but are required in high numbers. These include species that are commonly used for timber, fodder and hedging. In both cases, you still get high total profits but the low-priced species require higher investment. The low margin species attract customers who in turn buy the rare species that have high margins.

It is wise to stock a small number of rare species which can be introduced to customers as they buy other species. It is also good to diversify into other plants such as ornamental species. You can also stock, in small quantities, some species as 'loss leaders'. Loss leaders make a loss but are used to entice and keep customers.

16.5 How should I package my seed or seedlings?

The perception that NTSCs only sell seed in large quantities and at high prices has turned off many would-be clients. A kg of seed for many species normally produces thousands of seedlings, which in many cases is more than the retail customers need. It is good to assess the average quantities that your customers want, then pack and price them accordingly. It is important not to quote equal prices for small quantities of all species (such as US\$ 1 for 50 g of seed of any species) but to consider the costs involved in the production or collection of each species and your profit level. One can determine a constant weight, for instance, 50 g packets with different prices for different species, or a constant price for small packets of varying weight. For bulk orders such as those from NGOs or private companies, use the standard per kilogram price quotation. The packets should be of good-quality material and should be well labelled so that there is no confusion when supplying.

The packaging of seedlings also depends on your customers' requirements. There are some variable species that will sell for high prices but are considerably costly to produce. These include slow-growing medicinal species and grafted fruits. They are bought in small quantities but give high returns. Since customers are willing to spend more money on them than on other species, it is important to pack them in big attractive containers.

For common species required in tens or hundreds, simply pack them in small containers that will ensure quality without unnecessarily raising the production costs. In most cases, these species are sold in many neighbouring nurseries and you cannot vary the prices much from the average. It is therefore not feasible to invest a lot in their packaging.

Low-priced species that are required in high numbers, such as hedge and live-fence species, can be produced in bulk. If your market is mainly in the neighbourhood, you can raise them bare-rooted and pack them well in bulk

once they have been bought. Alternatively, you can produce them as many seedlings in a single large container and sell them as a unit, for example, US\$ 1 for a container of about 50 seedlings of *Dovyalis caffra*. Care should be taken to ensure that the appropriate stocking density is used in production so that customers are satisfied with the quality. Chapter 18 and the nursery manuals (available on the attached CD-ROM) explain more about bare-rooted seedling production.

It is worth emphasizing here that proper labelling of your products enhances the perception of their quality and value by your customers. The labels should include information on the species, their provenance, their variety name and characteristics, collection site details and details about you as the supplier. For example, a nursery operator in Meru, Kenya was able to sell seedlings of a good performing provenance of *Grevillea robusta* at about 4 times the amount he was selling the local material. He managed to sell the whole lot because he could clearly identify the different provenances, which can at times be hard if the labels are poor or non-existent.

16.6 How should I advertise my business, especially for new species?

Increasing customers' awareness of your product should increase the size of your market. ICRAF's work with nurseries shows that the majority of seed dealers in urban areas just pop up with small packets of seed at the beginning of the season and disappear without even leaving contacts. This does not work well for you as these nursery operators cannot point you to other potential clients. This however depends on the policy of seed supply in your specific country, especially as it concerns informal seed vending. You need to be sure of the legal status of your business. As a seed dealer, you should make your clients aware of the species you offer and when it is possible to offer them. Make yourself known through extension services, schools, relevant NGOs, agricultural exhibitions and even other farmers. If there is no way that buyers can contact you, you will always lose their trust.

Nurseries are often located in places that are not visible from the common roads. This means that only neighbours and occasional visitors will be aware of, and buy from them. To improve your visibility, place directional sign boards on the closest roads as well as posters in markets and nearby extension offices. Devise other ways of making yourself known, such as by organizing tree planting ventures, participating in agricultural exhibitions, putting up posters, and creating pamphlets and fliers about your nursery (see chapter 15).

It is often difficult to persuade farmers to buy a new species and it is a risk for dealers to invest in new species. You need to know why you should be selling a new species or variety. Why not stick with the tried and trusted species? What

is the tree good for? How long will it take for farmers to receive the benefits? Is there an end market for the tree product? If you can answer all these questions and persuade the farmer, you will be half way there (see chapters 5 and 6).

Normally, we promote new species or varieties because we know they have been tested elsewhere and have been proved to give some additional products or services that are new to customers. Your source of information can come in handy for promoting new species. If you have read about the species in journals or newspapers, it is good to make a copy of the article and copies of other leaflets with information about the species, and make them available to customers. Verify the details in such articles with relevant experts since sometimes unrealistic expectations are created with some species being promoted as wonder trees. When success stories on *Calliandra calothyrsus* started rolling out of Embu, Kenya, and articles appeared in a newspaper, the research centre received many calls from areas where the species had not been promoted.

It is also important to know that customers have very little information about alternative tree species that can provide the products they need. If you present new species as providing superior alternatives for the needed products, then you are likely to create a demand for the new species. Start with only a small quantity of the unknown species and increase supply as demand builds up.

16.7 How do I make sure that customers return?

Small enterprises rely very much on local business. If the local customers don't come back, the business can go under. You need to make sure that you supply the species that people want, at the right quality and time, in large enough quantities, plus any extra services demanded. This may seem difficult, but if you work together with other related enterprises, you shall meet all demands from customers. Adding something extra, such as new species and good background knowledge will impress your customers even more.

The quality of your products will also determine whether the customers will return or not. Some nursery operators indicated to us that they had stopped dealing with certain seed dealers because the dealers had sold them seed that would not germinate. As long as your customers can interact and evaluate your services then this kind of disappointment can result in more customers turning their backs on you. Some seed dealers have reported working with their clients (nursery operators) on the right germination methods to ensure that the seed has germinated. Other dealers only take part of the payment for seed and the rest once full germination has taken place. The information in this Toolkit on seed production, seedling quality and research should give you an edge over issues that may dissatisfy your customers.

Ask for feedback on the performance of your seed or seedlings after planting in the nursery or field. Be there to provide support and work out solutions

together with your customer if something goes wrong. Be ready to compensate the customer if the seed or seedlings fail due to no fault of the customer's. Ensure a close working relationship with most of your customers wherever possible. Be ready to answer questions and clarify any issues about the seed or seedlings that you supply, and receive any comments or criticisms positively.

16.8 How should I interact with my competitors?

Many seed dealers and nursery operators are in agreement that the demand for tree planting material is increasing. They also often find themselves with an excess supply of seed or seedlings of some species and lack some species that their customers desire. You might be surprised to find out that other dealers (your competitors) have what you do not have, but lack what you have. By working as an association of dealers, you can easily exchange seed or seedlings that are either in excess or scarce supply. It is possible to specialize in the species that you supply while being part of the network, to avoid unsustainable competition. The quality of your seed or seedlings as perceived by the users will place you above the rest, especially if you invest in good packaging.

When seed dealers and nursery operators view each other only as competitors, this can result in unhealthy competitive activities that can eventually be detrimental to their businesses. These activities include lowering prices to unsustainable levels, and selling off poor-quality material in order to reduce costs of collection/production. Working as a group will ensure that you can agree on reasonable prices that give you some profit, you can exchange high-quality seed, you can share market intelligence and access seed sources that you did not know about before.

A group can easily link with NGOs, private companies and other organizations that place bulk orders that a single operator may not easily handle. As a group, you can also ensure that the quality of materials is high, in comparison to unscrupulous middlemen who make customers distrust private seed and seedling dealers. A group can help solve common problems such as lobbying government and NGOs not to distort the market by supplying free or subsidized seed or seedlings.

However, working as a group is subject to group dynamics and not all groups will work. Seed or seedlings dealers who decide to come together as an association need to first discuss the benefits of working as a group. Patience is needed in the first few months or years as the group stabilizes. Some members may express dissatisfaction at some of the functions and may opt to leave the group while new members join the association. What is needed is a clear focus on the goals, especially by leaders. Transparency and accountability within an association should foster stability and the performance of the group.

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Chapter 17:

Tree Nurseries as an Enterprise

Summary

17.1 Why should I approach tree nurseries from an enterprise perspective?

Approaching the management of a tree nursery from an enterprise perspective orientates you towards the customer with a profit motive. This kind of focus means stocking and selling the tree species that customers value at an appropriate price as well as actively marketing your products.

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17.2 Is a tree nursery a good enterprise choice?

In order for a tree nursery to survive and even thrive as a business you need to meet farmers' needs. Approaching the management of a tree nursery from an enterprise perspective makes sure you pay attention to the customer. A tree nursery has the potential to generate significant income. Since a nursery provides a high-value product, it is suitable for a small farm. A tree nursery has relatively low start-up costs and can give a quick return.

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17.3 Why not operate a tree nursery on a not-for-profit basis and distribute seedlings free or subsidized to farmers?

There are many instances whereby tree nurseries are managed on a subsidized basis. In some cases, this is justified, but usually only as a short-term promotional activity for a new species, or if producing for own-farm use. As the only mode of seedling production and supply, free seedling distribution is not sustainable because it relies on outside financial support.

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17.4 How do I start a tree nursery enterprise?

Firstly, you need to make sure that there is a market demand for tree seedlings that has not yet been met. Secondly, you need to have a real interest in the enterprise. Thirdly, your site needs to have reliable access to water. The start-up cost is minimal, since most materials can be recycled or collected for free.

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17.5 What are the common problems associated with a tree nursery enterprise?

The common problems can be grouped into technical problems such as knowledge on seedling management or access to water; and organizational and market problems such as access to seed and not being aware of the market. You need to identify the biggest problems, so that you can focus on them.

By focusing on quality, quantity and choice, and balancing these against cost, many of the above problems are addressed. You want to make a profit, but customers should be happy to return to you.

More on page 210

17.6 How do I make sure I make money from this enterprise?

You cannot guarantee to make money from a tree nursery. But you can do a number of things to improve your chances of getting through to the next year. Work out how much your inputs are and make sure you are charging enough per seedling to pay for such inputs. Compare your prices and management practices with other tree nursery operators. Can you learn anything from them?

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17.7 How does working as a group fit into operating a tree nursery?

You may think that working with your potential competitors is not really a good idea. But working as a group can actually have a number of benefits for all parties. Collecting market information, meeting big orders and purchasing bulk quantities of hard-to-get seed is all much easier as a group. Nursery operators are often the best teachers of other nursery operators in workshops.

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17.8 How can a tree nursery be a sustainable business when trees are such a long-term investment?

We do not think people will ever stop wanting to buy trees, in fact we hope that in the future people will want more and more trees. The secret is to keep finding new markets, keep selling new products and maintain good quality at a reasonable price. Nursery entrepreneurs can use sophisticated marketing to promote new tree species and varieties for new tree-based land-use systems.

More on page 212

Introduction

This chapter outlines the efforts that need to be made in order to develop a small-scale private tree nursery enterprise. The constraints commonly faced by nursery operators, and options to deal with those constraints within an enterprise model, are discussed. This chapter is an illustration of the application of the business approach to tree nurseries (see chapter 15).

17.1 Why should I approach tree nurseries from an enterprise perspective?

Approaching the management of a tree nursery from an enterprise perspective orientates you towards the customer. The profit motive is incredibly strong, especially if a household is depending on it. A customer focus means stocking and selling tree species that farmers value at an appropriate price. It also means active marketing of your product. No buyers will come if they do not know about you, and new species will not be bought if you do not promote them. If the nursery does not make a profit, there is a temptation to distribute species that you think the farmer should have without investigating or demonstrating whether farmers really value the species.

17.2 Is a tree nursery a good enterprise choice?

Tree nurseries have the potential to generate significant income. We have seen urban and peri-urban tree nurseries that are producing quite significant annual returns for a farm enterprise. Table 17.1 shows some results from a workshop on financial management and marketing. Here we found that a wide range of species can have healthy margins (gross margin = sale – cost). When taken together, the income from the tree nursery is quite good, even for a small tree nursery. However, when you take a closer look at table 17.1 then you may notice that the Tigoni nursery sells *Dovyalis caffra* at a loss of Ksh -2 per seedling. When you only look at the total gross margin of a nursery, then you may not realize that one or several species are sold at a loss. In our experience it is often the case that some species are sold at a loss in nurseries, and that is why we recommend nursery operators do a gross margin analysis on a species-by-species basis. Our advice to the operator of the Tigoni nursery would be to stop production of *Dovyalis caffra* and focus on production of other species, or otherwise increase the selling price of this species to recover production costs and make a profit.

The enterprise is suited to small-sized farms since it produces a high-value product. This is why many of the peri-urban nursery operators around

Table 17.1 Gross margins of four different species for nurseries around Nairobi [figures are in Kenya Shillings (Ksh)]

Species	Ngatu nursery	Bibirioni nursery	Tigoni nursery	Grace nursery	Kiambaa nursery
<i>Dovyalis caffra</i>					
• Production	11,500	20,000	9,000	1,500	1,000
• Gross margin per seedling	3	1	-2	1	1
• Total gross margin	34,500	20,000	-18,000	1,500	1,000
<i>Grevillea robusta</i>					
• Production	200	2,000	4,300	100	0
• Gross margin per seedling	30	10	10	10	0
• Total gross margin	6,000	20,000	43,000	1,000	0
<i>Persea americana</i>					
• Production	0	0	73	150	20
• Gross margin per seedling	0	0	100	100	50
• Total gross margin	0	0	7,300	15,000	1,000
<i>Prunus africana</i>					
• Production	0	0	20	100	20
• Gross margin per seedling	0	0	20	100	20
• Total gross margin	0	0	400	10,000	1,400
Total gross margin for all species	40,500	40,000	32,700	27,500	3,400

Nairobi, Kenya, chose to run this business. If the market is big enough, a nursery enterprise can be worth pursuing full time. This has been the case in peri-urban areas where there is a market from the immediate area, from urban residents, and from people who are travelling to the rural areas.

In rural areas, a nursery enterprise is ideally suited to fit in with other farm enterprises. For example, most of the members of the group that the ICRAF works with in Meru, Kenya, rank their nursery enterprise at number 1 or 2 of all the enterprises they run (table 17.2). They estimated that the tree nursery contributes on average 48% of farm income (table 17.3).

Table 17.2 Position of tree nursery in rank of farm enterprises according to income generated

Nursery rank	Number of nurseries	Percentage of nurseries
1	7	35
2	8	40
3	4	20
4	0	0
5	1	5

Table 17.3 Distribution of percentage contribution to total farm income for 20 tree nurseries in Meru District

Percentage contribution to the total farm income	Number of nurseries
15	1
20	1
30	3
45	1
50	2
60	2
75	1
80	2

17.3 Why not operate a tree nursery on a not-for-profit basis and distribute seedlings free or subsidized to poor farmers?

There are many instances when tree nurseries are managed on a not-for-profit (either free or at subsidized prices) basis. It is an attractive and relatively simple project for many rural development organizations. Seedlings can be grown cheaply and easily, farmers readily accept them, and trees are considered a good thing by nearly everyone. It is also easily measurable – how many trees are planted or handed out?

Supplying free seedlings can be justified if it is a short-term promotional activity, for example, kick-starting a tree planting project or introducing a new and unknown species. Private tree nurseries often give free seedlings of a new species together with a bigger purchase that a farmer has made. Then, if

farmers like the trial seedlings and want more, they can come back and purchase them.

The one instance of a not-for-profit tree nursery that should not be discouraged is if production is only for own-farm planting. Then enterprise principles do not play such a big part. It is still important for the farmers to analyse which option between either buying the seedling or producing it themselves is more cost-efficient. You will see in the next question that this is one way that tree nursery enterprises start off.

The main point of the response to this question is that entirely not-for-profit tree nurseries cannot fit into the model of a sustainable seed and seedlings system because they will always need outside financial support. Even more serious is the market distortion that the not-for-profit tree nurseries cause (see box 17.1). Potentially viable and sustainable enterprises can be pushed out of the market due to subsidized seedling supply.

17.4 How do I start a tree nursery enterprise?

Firstly, you need to make sure there is a market demand for tree seedlings and that this need is not being met by existing tree nurseries or home supply. Follow some of the guidelines on marketing in chapter 16. For example, a project may have introduced some useful tree species in your area for a short time, then left after creating a demand (such as for *Calliandra calothyrsus* in parts of eastern and Central Africa). You can choose to fill the gap by supplying such species among others. If you are an organization thinking about funding the start-up of new tree nurseries, do a thorough survey of the area to make sure there are no nursery operators serving the area already. It may be a better option to assist other nursery operators to improve their business than to put them out of business with a subsidized nursery enterprise.

Box 17.1 Subsidized seedlings

ICRAF conducted a financial management and marketing workshop for tree nursery operators in Meru, Kenya. We did gross margin analysis for a number of species that they sold. It turned out that for a number of species, particularly the common ones like *Grevillea* and *Eucalyptus*, the nursery operators were hardly making any profit, and quite often, they were making a loss. We asked why this was so and why they did not raise their prices by 1 or 2 Ksh. The farmers responded that their customers demanded that price because when the Forest Department used to supply seedlings, they sold at a subsidized price of Ksh 3 (US\$ 0.04) each, which is a ridiculously low price. These nursery operators are having trouble keeping their business going in this distorted market.

Secondly, when you start up a nursery, you need to be interested and committed to the enterprise. Table 17.4 provides an insight into why some tree nursery operators in Meru, Kenya, decided to start tree nurseries. Many started by producing seedlings for their own farm. Slowly, their business expanded to supply neighbours and then other people. The second reason was the farmers' passion for trees. A farmer is often successful when he or she makes a choice to excel at his or her chosen vocation. Projects had a significant effect, as did diversifying income and conservation interests. It may be surprising to note that income generation was not a big motivating factor when these farmers started the enterprise. The nursery operators only realized later that having a market for their seedlings was important. That is why we need to focus on the income-generation aspect of tree nurseries.

Thirdly, when you start up a nursery, your site needs to have reliable access to water. While other technical aspects of quality seedling production are covered in chapter 18, a nursery operator has limited options when it comes to manipulating water supply. Without a reliable water supply, your tree nursery will always be vulnerable. If your compound does not have access to water, choose another site if possible.

Nursery start-up costs are very minimal, as most things can be collected (like seed) or found and recycled (like pots). By starting small and reinvesting the profit, a good tree nursery can grow very quickly and give a quick return, since you can sell seedlings within a few months. Wheelbarrows, watering cans and shade netting are not essential for a small start-up tree nursery.

Table 17.4 Reasons for starting a tree nursery taken from Meru operators' workshop, 13–15 August 2003

Reasons for starting a tree nursery	Number of farmers
Own tree-planting objectives on own farm	9
For the love of tree nurseries, passion	8
Diversifying farm enterprises to occupy family labour/time	5
Restoration of endangered species	5
Aesthetic value of trees	4
Business (source of income)	3
Reforestation in government forests	2
Testing new tree species	1

17.5 What are the common problems associated with a tree nursery enterprise?

Throughout ICRAF's surveys and other people's work, a number of problems have been identified. These can be grouped into technical problems, such as knowledge on seedling management or access to water; organizational and market problems, such as access to seed; and not being aware of the market. Figure 17.1 illustrates these problems. There are also knowledge and access constraints, which form part of the market problem.

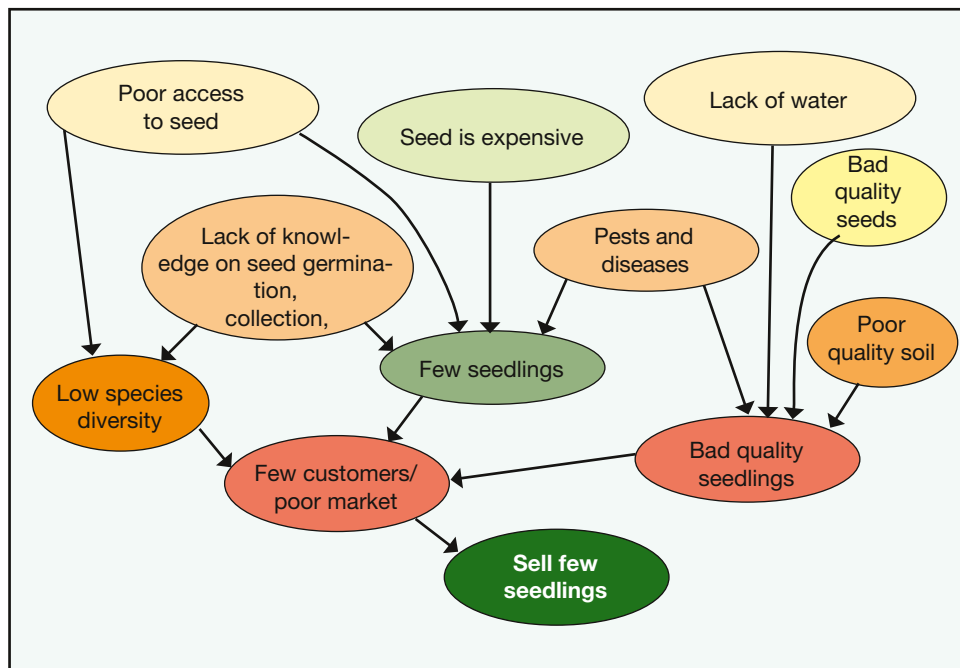
Three major problems – bad-quality seedlings (**quality**), too few seedlings (**quantity**), and low species diversity (**choice**) – often result in few customers and low sales.

You will need to do some market research to find out what balance you want between quality, quantity or choice (see chapters 12 and 16). Quantity and choice refer to how much of each species you stock. By doing some market research you can work it out.

17.6 How do I make sure I make money from this enterprise?

You cannot guarantee that you will make money from your enterprise. But you can do a number of things to improve your chances of getting through to the next year.

Figure 17.1 Examples of constraints in seedling supply, and how they are linked



ICRAF has conducted workshops in which a simple gross margin analysis was carried out on the tree nursery enterprises. A gross margin analysis enables you to work out how much your inputs are and whether you are charging enough per seedling to make a profit. If the tree nursery is a part-time business, you may be surprised to find out that other farm enterprises are subsidizing the tree nursery or *vice versa*. By calculating gross margins in a workshop environment, comparisons of costs and management practices can be made between tree nursery operators. For example, it is possible to see what buying water or manure does to the gross margin; or how stocking a few ornamental species keeps sales going through the dry season.

A recording system keeps track of your costs and sales throughout the year, and helps you reflect on what is happening in the tree nursery. Records also simplify the gross margin analysis at the end of the year. Question 16.3 provides details on the information needed to calculate a gross margin analysis. Good record keeping is therefore very important.

17.7 How does working as a group fit into operating a tree nursery?

By ‘group’ we do not mean a group nursery where farmers come together and start a common nursery. We mean, different people with their own private nurseries coming together as an **association**, in order to better handle some constraints. Although working with your potential competitors may not seem like a really good idea, it can actually have a number of benefits for all parties. ICRAF has learnt this through working with groups of nursery operators around Nairobi and in Central Kenya (box 17.2).

It was found that project technicians are often not the best people to teach tree nursery management. A number of operators have been in the business for over 15 years and they really know how to grow a quality seedling. As a group, the operators can exchange knowledge and ideas and train each other. They

Box 17.2 What operators said one year after a workshop that brought them together

We learned to exchange ideas and seed with other operators.

We learned to market seedlings through other nursery operators.

We were able to form an association, so that we now visit each other to learn more and more, and exchange different species.

It has enabled us to become advisors to others.

also have access to, and know of, different tree species. Visiting each other allows tree nursery operators to exchange cuttings and seed. For example, at the third meeting of the Nairobi tree nursery operators' self-help group, everyone took cuttings, swapped packets of seed, and asked about the species they had not seen.

As a small enterprise, it may be difficult to collect all the market information you need to take full advantage of the available market. Working together with other tree nursery operators allows you to share the job. Our experience has shown this is more difficult to implement, especially in the absence of written records. But even oral communication of market information is useful and better than none at all.

Sharing orders is another thing that operators can do together. As a small enterprise, you are unlikely to stock in high numbers all the species that are demanded. If a big order comes in, you can share it with a neighbouring operator, because if you do not do this, you might risk losing the whole order.

Since many people say tree seed is difficult to procure, bulk ordering as a group can give access to better quality seed as well as hard-to-get species. Ordering a few kilograms of seed with group members makes more sense than ordering a few grams. The Nairobi group has done this with neem seed from the Kenyan coast.

It is much easier for NGOs, researchers and extension agents to interact with a group than to meet each operator individually. The group can also put forward their concerns in a better manner.

17.8 How can a tree nursery be a sustainable business when trees are such a long-term investment?

For a start, there are tree nursery enterprises that have existed for over 20 years. Although trees take a long time to grow and live for many years, seedling demand is always high. In fact, in the future, people will want more and more trees. An interview with informal tree seed dealers revealed that all saw tree seed demand increasing by the day. People also appreciate having more tree species, especially indigenous ones, on their farms. More markets are also emerging for tree products other than timber. Tree nurseries can be a part of the driving force to plant more trees. The secret is to keep finding new markets and to keep selling new products. It would be good to see tree nursery entrepreneurs using sophisticated marketing to promote new tree species and varieties for new tree-based land-use systems.

Information compiled by:

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Chapter 18:

Tree Seedling Quality

Summary

18.1 What is meant by the quality of a seedling?

The quality of a seedling is influenced by its physiological and genetic qualities. Quality is also a measure of how well the seedling addresses the desires of the client. Farmers, for instance, are often interested in seedlings that survive well when planted on the farm and mature early.

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18.2 What influences the physiological quality of a seedling?

The most important aspect of a tree seedling is its ability to quickly establish itself when planted out in the field. However, many buyers judge the quality of seedlings by the physical appearance of their leaves and stems: large, healthy seedlings are preferred. A seedling of high quality is distinguished by a strong well-developed root system, leaves that have adapted to open field conditions, sufficient roots to support the leaves and stem system, and enough food reserves to survive the time it takes to get used to the field.

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18.3 How can I achieve good physiological quality of seedlings at germination?

Firstly, you need to collect (or buy) seed with high germination potential so that a high germination rate is achieved within a short time. Once the seedlings germinate, there should be minimum physical handling and, where it cannot be avoided altogether, minimum disturbance. With the exception of small seeds sow seeds directly into containers to avoid pricking out seedlings.

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18.4 Can the substrate or containers I use in my nursery affect the quality of the seedlings?

A good (nutritious and porous) substrate will ensure that seedlings are healthy and look attractive. Seedlings show lack of nutrients either by leaf yellowing (chlorosis) or by stunted (very slow) growth. Low porosity leads to restricted

air and water flow, causing stunting or very shallow roots. The seedling containers should ensure proper root development. The choice of container is determined by the cost, the species, their purpose and their size.

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18.5 What other nursery practices are likely to affect the quality of my seedlings?

Too much water or too much shade often lead to extra humidity and allow diseases such as damping off to develop. The intensity of watering and shading should reduce as seedlings mature. Water and shade should almost be withdrawn as seedlings near the planting out stage. The extent of watering or shading will also depend on weather conditions and should be less on cold and/or rainy days.

Attacks by pests and diseases result in seedlings that are visibly unattractive and of poor quality. Practising proper nursery hygiene involves making sure that the nursery is not damp, that all trash is disposed of, that tools are cleaned every time they are used, and that everything coming into the nursery is free from pests or pathogens.

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18.6 What influences the genetic quality of a seedling?

This quality aspect depends on the seed that has been procured. A wide genetic variability in a seed lot and thereafter of a seedling batch, provides protection against a future loss in performance from in-breeding. Individual nursery operators who collect seed for themselves are advised to follow the guidelines and ensure they collect from many good-quality mother trees that are appropriately separated. Matching species and provenances to planting sites is the most important genetic quality issue. Tree species from very cold areas will generally do very poorly in warm areas and *vice-versa*.

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18.7 How can I ascertain the genetic quality of the seed that I buy from others?

Buy from known seed dealers or reliable seed suppliers listed in the ICRAF Tree Seed Suppliers Database. Get all the information about the seed's source and, if possible, pool seed of the same species coming from the same area with other nursery operators.

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18.8 How can I recognize good-quality seedlings?

By checking the diameter of the seedlings compared to their height, and by checking that the foliage (leaves) looks green, healthy and well-fed. Check that roots are not coiled around and within the container and that the seedlings do not have roots that have penetrated the container bottom into the soil. Find out when the seedlings were established so you do not buy overgrown ones. Also find out about the seed source in order to establish a match for your area.

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Introduction

As people plant more trees, the demand for seedlings increases. In turn, the number of tree nurseries that supply seedlings also increases. This chapter guides farmers to recognize quality tree seedlings and explains to nursery operators how to produce good-quality seedlings.

18.1 What is meant by the quality of a seedling?

Depending on their interest, different people mean different things when they talk of seedling quality.

- Farmers are interested in seedlings that will survive well, establish quickly, and produce the required products early. From a quick look at the nursery he or she will only judge by the size of the seedling and the colour of the leaves.
- A nursery operator is interested in seedlings that look healthy and attractive to clients and will sell at a good price. It is good for the nursery operator not to spend too much money on producing the seedlings in order to raise income from them.
- A scientist wants seedlings that will establish quickly, are uniform, and produce the desirable research results with little unaccounted variability.

Many of these aspects are physical and can be quickly determined within a short period of time. However, as stewards of nature, we should all be interested in propagating trees that are appropriate for the site, and trees that produce the goods and services that we all need. The seedlings must carry adequate genetic variability within them (box 18.1). The nursery operator or manager must try to satisfy all these interests while also satisfying the need for profit. Considerations of costs and expected prices of the seedlings determine the quality that a nursery operator should achieve for the seedlings.

18.2 What influences the physiological quality of a seedling?

The most important aspect of a tree seedling is its ability to establish itself quickly when planted out in the field. The ability of a seedling to establish itself also depends on the planting site; thus, the seedling must be correctly selected for the planting site. This means that the qualities of a seedling to be planted in a humid area differ from those of a seedling that is planted in a dry area. However, many seedling buyers judge the quality of the seedlings by the physical appearance of leaves and stems: large, healthy seedlings are preferred. Assessing the roots is destructive; hence, it is rarely done. However, if the seedlings perform poorly when planted on a farm because of a poor root system, the farmer will not buy from the nursery again. Therefore, nursery operators need to be careful about all quality aspects, especially the root

system. We encourage farmers to check the root systems or sample them before planting seedlings in the field.

The following is a summary of physiological qualities of a high-quality seedling:

- A strong well-developed root system (not coiled) that ensures an ability to produce new roots quickly.
- An ability to quickly get established after being planted on the farm and to start moving nutrients from the soil to the leaves.
- Leaves that have adapted to open field conditions (sun-adapted foliage).
- Sufficient roots to support the leaves and stem system (root to shoot ratio).
- Enough food reserves to survive well as the seedling gets used to the field.
- For species that need micro-organisms (such as mycorrhizae or rhizobia) in order to grow, seedlings should be strengthened by adequate inoculations.

18.3 How can I achieve good physiological quality of seedlings at germination?

As a nursery operator, the first thing that you need is to collect (or buy) seed with a high germination potential so that a high germination rate is achieved within a short time. Where necessary, you should also carry out the right pre-treatment of seed (see chapter 11). Once the seedlings germinate, there should be minimum physical handling of them and, where it cannot be avoided altogether, minimum disturbance. Except for small seeds, sow seeds directly into containers to avoid pricking out seedlings.

Pricking out, or transferring seedlings that have just germinated into containers, is a delicate operation which often leads to seedling root deformity

Box 18.1 Seedling quality

A high-quality seedling meets a buyer's expectations or standards of performance on the planting site. Although quality is mainly judged in terms of physiological quality, genetic quality also applies. Physiological quality is the physical appearance of a seedling and the aspects that ensure its ability to establish quickly when planted in the field. Genetic quality is the combination of different traits from the parents of the plant, which ensure that it can establish well in a given area, continue producing high-quality products in the future, and that the offspring will also do the same. While poor physiological quality can be easily observed at the nursery level or soon after field establishment, the consequences of poor genetic quality are only discovered after a long time. Poor genetic quality has widespread future effects, such as maladaptation and inferior products from trees on many farms. Therefore, it is important for nursery operators to ensure that their seedlings have both aspects of quality and that farmers are adequately informed on these quality aspects.

and extends to poor root systems in the resultant trees. As far as possible, pricking out should be avoided and where it must be done, a lot of care should be taken. Big seeds should be sown directly into containers with two or three seeds sown in each container depending on the germination potential of the seed lot. For small seeds, prick out immediately after germination. Use the appropriate density of seedlings in the nursery bed.

18.4 Can the substrate or containers I use in my nursery affect the quality of the seedlings?

It is good to sow seeds or prick seedlings out to a **substrate** (the soil/sand/manure mixture in which the seedling is planted) that is nourishing. A good substrate ensures that seedlings are healthy and look attractive. Many small-scale nurseries use the common soil from the nursery site. Often, this soil is depleted of nutrients and does not have enough spaces (pores) for air and water to get to the roots, or for roots to grow freely. If your seedlings suffer from the lack of nutrients, they exhibit leaf yellowing (chlorosis) or stunted (very slow) growth. If the substrate does not have enough spaces, the flow of air and water is restricted. This restriction leads to stunting of the seedlings or very shallow roots. It is recommended that you mix manure (preferably compost), sand and forest soil well to prepare a good substrate. The best substrate mix may depend on the area where you operate. You may want to discuss your mixture ratio with the area forest or agricultural extension officer.

The **containers** for seedlings also determine the quality of seedlings in the nursery since they affect the root strength. Although some containers such as **root trainers** have the advantage of directing roots downwards upon hitting the container walls, they might be expensive for many nurseries. Polythene bags are cheap but have the disadvantage of letting roots coil or grow in spirals when they reach the container wall, eventually leading to a weak root system if seedlings overgrow in the bags. Seedlings with coiled roots are not well-grounded in the field after planting.

Choose the type of container by considering the species, their purpose and their size.

- Bigger pots should be used for species that stay longer in the nursery (such as indigenous medicinal species) so that roots take a long time to reach the container sides. Use bigger pots for other species for which you intend to conduct further nursery practices, such as grafting.
- Transfer into bigger containers seedlings that were meant to stay for a shorter time but were not planted in time in the field (possibly because they were not purchased).
- If possible, raise open-bottom container seedlings on raised beds to avoid root-pruning that may damage or even infect the roots with diseases. On raised beds, roots are air-pruned in containers with open bottoms. These beds can be made using locally available materials like bamboo or wooden

planks placed across logs or dug out holes. In areas that experience water scarcity, this may not be a viable option.

- Sow seedlings meant for your own planting or for the neighbourhood directly into raised beds for bare-rooted seedling production (Swaziland beds) or as multiple seedlings in large containers. This should preferably be done for seedlings that are required in large numbers and do not need a long time in the nursery, such as hedge or fodder species.

18.5 What other nursery practices are likely to affect the quality of my seedlings?

Watering and shading can affect the quality of seedlings and as a nursery operator you should be careful how you conduct these practices. Too much watering or shade can lead to excessive humidity which favours diseases such as damping off. The intensity of watering and shading should be reduced as seedlings mature, and should almost be withdrawn as seedlings near planting out (hardening-off process). The extent of watering or shading also depends on weather conditions and should be less on cold and/or rainy days. The following tips should be of help:

- Ensure minimum movement of seedlings to and from beds.
- Use movable shading systems depending on how much shade a batch of seedlings need. Movable shades can be shade nets or a roll of bamboo or papyrus.
- Water your seedlings according to their requirements, and not by fixed regimes such as twice a day. With practice, you can learn the water requirements of various species by feeling their leaves.
- Water the seedlings using a watering container with small holes so as to protect leaves and young seedlings from damage.
- Water young seedlings more frequently but reduce the frequency as they mature.
- Adjust your watering and shading according to the weather conditions of each period.
- Reduce watering and shading as seedlings near field planting or get ready for sale to ensure they are conditioned for the field (hardened).

Attacks by **pests and diseases** in a nursery result in poor-quality seedlings, which are visibly unattractive. Proper nursery hygiene together with appropriate watering and shading ensure healthy seedlings. The nursery should not be damp, all trash should be disposed of, tools should be cleaned every time after work and everything that comes into the nursery should be free of pests or pathogens. A major entry point for pests, pathogens and even weeds is the substrate (sand, forest soils, organic manure and others). The substrate should be sterilized using hot steam or sunlight (solarization). During solarization, moist soil is covered with polythene sheets and left in the sun for some time to kill any pathogens in the soil. Preventive maintenance by maintaining hygiene is better than

curative approaches to pests and diseases. Curative approaches involve a lot of chemical spraying and may not improve the appearance of the seedlings.

18.6 What influences the genetic quality of a seedling?

A seedling's genetic quality largely depends on the seed that has been procured. Most nursery operators in the tropics collect all or some of the seeds by themselves, while a few buy from seed centres and seed vendors. Wide genetic variability in a seed lot and thereafter in a seedling batch, provides protection against future losses in performance from inbreeding (see chapters 8 and 12). As has been stated earlier, the genetic quality of a seedling cannot be judged in the nursery by clients but it affects the performance and productivity of the trees in future. Chapter 8 explains how to collect seeds with a wide genetic base. Individual nursery operators who collect seed for themselves are advised to follow the guidelines and collect seed from many good-quality mother trees that are appropriately separated.

Matching species and provenances to planting sites is the most important genetic quality issue. Tree species from very cold areas will do very poorly in warm areas and *vice-versa*. Seedlings from arid zone species stunt and appear sickly in cool nurseries.

As a nursery operator you should:

- Understand the climatic requirements of your species stocks so that you can provide your clients with the right information.
- Know the provenance (source and climatic conditions) of the seeds you have collected.
- Label your seedling batches clearly in order to distinguish species and provenances, especially if there is more than one of the same species, or several closely related species (see box 18.2).
- Direct each client to the right batch depending on the area the client intends to plant his seedlings.

Box 18.2 Labelling of seedlings

Poor labelling can have disastrous results when closely related species are confused and sold to clients. In a case study in Embu (Kenya), a nursery that stocks *Leucaena trichandra* and *Calliandra calothyrsus* seedlings had labels exchanged when shoot pruning was being done. The seedlings were then transported to different destinations. Farmers in a semi-arid zone where *Calliandra calothyrsus* could not do well ended up with this species instead of *Leucaena trichandra*. Their disappointment was great due to poor performance. Such results lead to lack of confidence in the nursery by buyers. There can also be confusion between related species, such as *Melia azedarach* being sold as *Azadrachta indica* only to disappoint the farmer after several years on the farm when it doesn't provide the medicinal products needed.

18.7 How can I ascertain the genetic quality of the seed that I buy from others?

The following checks will help you to buy good-quality seed.

- Buy from known dealers to whom you can give feedback on seed performance if you are operating a small-scale nursery. For nurseries that buy in bulk, such as NGOs, some reliable seed suppliers can be found in the ICRAF Tree Seed Suppliers Database.
- Insist on information about the seed source: area climatic conditions, number of mother trees and how far apart they are.
- For seed dealers operating close to you, insist on having access to their seed sources and establishing a close working relationship.
- Pool seed of the same species and from the same area with seed from other nursery operators, then share the seed proportionally in order to widen diversity.
- If you cannot afford to buy all your seed from the source of the highest quality, once in a while buy small quantities of seed from acknowledged seed centres (such as NTSCs) and bulk with seed procured from elsewhere.

18.8 How can I recognize good-quality seedlings?

- Checking that the diameter of the seedlings is large relative to their height.
- Ensuring that the foliage (leaves) look green, healthy and well-fed.
- Checking that large seedlings do not have roots that have penetrated the container bottom and grown into the soil.
- Asking the nursery operator when the seedlings were established (if there are no records) so you do not buy overgrown seedlings that will not establish well.
- Checking sample seedlings to ascertain that their roots are straight and not coiled around and within the container.
- Asking the nursery operator about the seed source in order to establish whether it will match with your area – if possible also asking about the mother trees to see if they are of suitable quality.
- Using any other criteria you can devise to check for seedling quality from the above information.

The production of high-quality seedlings is a real investment on the part of the nursery operator. Farmers cannot expect to get free seedlings since the price they pay needs to cover this investment. The nursery operator can only produce seedlings of as high a quality as farmers are willing to pay for. Think about buying good-quality seedlings as an investment: the quality of the seedling is a guarantee of obtaining a good product or service from the tree that will grow from the seedling.

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Chapter 19:

Tree Nursery Operators as Extension Agents

Summary

19.1 Why would extension agencies wish to use tree nursery operators as deliverers of extension messages?

- To develop local skills and empower local people to solve their own problems.
- To facilitate the opening up of communication channels between nursery operators and their clients, thus enhancing the flow of information.
- Field experiences have proved that farmer-to-farmer technology transfer is an effective extension approach for sustainable technology dissemination, bearing in mind the limited human resources facing extension agencies today. These core farmers can use the local language to simplify technical information from extension agents and thus ensure it is clearly understood by other farmers.
- Nursery operators with lower costs quickly reach more people.

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19.2 Who is the target audience for extension messages from tree nursery operators?

- Seed and seedlings buyers.
- Youth groups.
- Church groups.
- Schools.
- NGOs and extension agencies.
- Other tree nursery operators.

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19.3 What training do tree nursery operators need to work effectively as extension facilitators?

- Training on products and services that trees can provide.
- Training on planting, tending and management of trees on farms for desired services or end products.

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19.4 What kind of approaches should tree nursery operators use in extension?

- Facilitation approaches.
- Participatory approaches that use a two-way communication of knowledge.
- Open-ended approaches.

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19.5 What problems could tree nursery operators encounter when they share technical and entrepreneurial information?

- Conflict of interest (as they need to work with potential competitors).
- Poor attendance at meetings.

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19.6 What abilities should a tree nursery operator have in order to work as an extension agent?

- Ability to communicate with the target audience.
- Knowledge and experience of nursery operations.
- Relationships of trust with other tree nursery operators.
- Ability to mobilize groups of tree nursery operators.
- Ability to put into practice the technology for which instruction is being sought from farmers and other nursery operators.
- Good knowledge of the language used to communicate with the audience.

To ensure a wider spread of information through the community, it is advisable to have a balance of gender and age amongst selected nursery operators.

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19.7 How can the technology being disseminated be sustained?

- Capacity building of tree nursery operators' (or farmers') associations and extension staff.
- Facilitation of access to and interpretation of market information.
- Participatory market chain analysis for tree seed and seedlings.

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Introduction

An in depth understanding of farmers' needs can contribute to an increased demand for tree planting, leading to a sustainable and healthy seedling market. The extension system proposed in this chapter is a capacity building process that trains nursery operators in specific technologies and also facilitates sustainable and ongoing access to knowledge and information.

Extension services facilitated by tree nursery operators will provide the following:

- Sound technical information to farmers and other users of seed or seedlings.
- Ongoing work with nursery operators' associations in order to build members' capacity and help them to solve their own marketing problems.
- Working with all the associations' members while avoiding working with a few selected farmers.

19.1 Why would extension agencies wish to use tree nursery operators as deliverers of extension messages?

There are various reasons why nursery operators should be incorporated into extension systems:

- The public extension system has broken down due to many challenges such as laying-off of staff, lowered budgetary allocation, and an inability to keep up with changing technology and information systems, leading to limits on the number of farmers it can reach and whose needs it can meet effectively.
- Extension approaches are changing, with greater emphasis being placed on reducing government involvement and focusing on local needs. Tree nursery operators are in contact with many farmers due to their tree seedling or seed marketing efforts and provide a point of contact for many farmers interested in planting trees. Being part of the local community, they are a good channel where local people can be empowered to solve local problems credibly and sustainably.
- To develop local skills and empower local people to solve their own problems. Working with an association or groups of nursery operators allows extension staff to interact with larger numbers of tree nursery operators at the same time, thereby using scarce resources efficiently.

19.2 Who is the target audience for extension messages from tree nursery operators?

Any customer of a nursery operator is a target audience for extension messages. Nursery customers should not only be provided with seedlings, but also with extension messages on the proper use of those seedlings.

Target groups may include any of the following:

- **Seed and seedling buyers:** These are customers for tree seed or seedlings from any nursery, or people issued with free seedlings or seed from a central nursery.
- **Youth group nursery operators:** This is a group formed with the aim of making money through the sale of seedlings alongside other activities, such as health education or religious fellowship.
- **Church group tree nursery operators:** These are church groups that manage a tree nursery to generate income for the members or to distribute seedlings to the members' farms.
- **School tree nursery operators:** These are members of a club or group of school pupils and teachers that are involved in tree nursery establishment and management. Their seedlings may be raised for use in the school compound or for sale.
- **NGOs and extension agencies:** These are institutions that provide extension services, for example, forestry departments, ministries of agriculture, ministries of livestock, institutions of higher learning, prisons, NGOs, faith-based organizations, national research institutions with an agroforestry extension component, or ICRAF.
- **Other tree nursery operators:** These may be a women's group, a cooperative, a tea association, individual nursery operators or a group of farmers formed purposely as a merry-go-round for money-making and tree nursery operation activities.

19.3 What training do tree nursery operators need to work effectively as extension facilitators?

Tree nursery operators require information in both technical aspects of nursery management and entrepreneurship as well as communication tools and skills. Some examples were given in chapters 17 and 18. However, experience has shown that the hands-on experience of nursery operators who have been operating for many years often provides them with the best technical knowledge that can be shared.

Tree nursery operators require training in such technical aspects as planting and tending trees in the field, tree seed production, other indirect tree-dependent enterprises such as bee keeping and the economic importance of both locally known and unknown species.

- The tree nursery operator needs to know the techniques for planting and tending trees, so that they can be more effective in extension activities. Customers prefer buying from nursery operators who can advise them on seedling production matters like the best time to plant trees (e.g. the second week of the rainy season when there is enough water in the ground); the best minimum size of a seedling (at least 1.0–1.5 ft tall); the size of the holes in which seedlings should be planted (e.g. 1.5 ft × 1.5 ft, or at least the distance from the wrist to the elbow). Nursery operators should also know the right spacing for the most popular species.
- In addition to seedlings, tree nursery operators could also offer other items necessary for tree establishment, such as fertilizers, manure and nursery tools. They could also sell tree seed to customers who wish to set up their own nurseries. Follow-up services on the performance of the seedlings sold can give a boost to an operator's business as the operator builds a rapport with local farmers.
- Tree nursery operators could also benefit from some training in communication tools and skills used by participatory extension practitioners.

19.4 What kind of approach should tree nursery operators use in extension?

Approaches that tree nursery operators could use include:

- **Facilitation approach extension:** Participation in problem identification and technology development are not enough. Hence, there is a need to consult with farmers not only about the questions that they wish to resolve, but also the manner and ways in which the issues preventing access to various solutions, including technologies, could be resolved. Tree nursery operators' associations should serve as the contact point between nursery operators, researchers and extension agents. This could facilitate the incorporation of the knowledge and experience of nursery operators into technology generation and dissemination activities.
- **Participatory (active involvement) approach:** This is a two-way communication of knowledge that involves participation not only in technology development, but also in institutional and social reform. It strengthens the links between indigenous and scientific knowledge. In this approach, tree nursery operators are involved in the design, decision-making process and implementation of an extension activity. It includes the monitoring and evaluation with clients and farmers of species demand, tree products and services sought by surrounding communities, seedling survival, prevailing tree management practices and farmer knowledge gaps. It is a process designed to develop and strengthen the local capacities of rural people to gain responsibility for and authority over local resources and to contribute effectively to all decisions on how these resources are used. The goal is empowerment of the intended beneficiaries to enhance decision making, innovation and management of their resources and their livelihoods.

- **A tree nursery operators' association can reach more farmers by organizing and participating in communal tree planting days:** The Nairobi-Kenya Tree Nursery Association has organized a number of these in school compounds where they invite the school children, their parents and local leaders and extension staff to participate and exchange ideas on tree planting. They also participate in agricultural shows and share information on tree planting issues as they market their seed and seedlings.
- **An open-ended approach:** This entails the use of various extension tools and methods, for example, training, seminars, workshops, public meetings, field days, excursions, working with other local groups, and the use of conventional advisory service methods in a loose iterative manner as required (see chapter 3).

19.5 What problems could tree nursery operators encounter when they share technical and entrepreneurial information?

Nursery operators could encounter various problems when facilitating information exchange. These include:

- **Conflict of interest** as they work with potential competitors. Tree nursery operators need to understand that teamwork enables them to collect market information, meet large orders and purchase bulk quantities of hard-to-get seed. It is also easier to get training as a group.
- Poor attendance at meetings.

19.6 What abilities should a tree nursery operator have in order to work as an extension agent?

- Knowledge on the operation of tree nurseries or seed production and a reasonable level of formal education.
- Relationships of trust with other nursery operators or farmers: people will listen to the advice and suggestions of a tree nursery operator whom they feel they know and personally like and whose knowledge they respect.
- Ability to mobilize groups of operators: the personal influence of an extension worker is important in securing cooperation and participation in extension activities and in the adoption of improved practices.
- Mastery of the language used for communication to the audience: the nursery operator should be able to communicate in the local language or dialect.

Ensure a balance of gender and youth amongst selected nursery operators. Different age groups and sexes should be appropriately represented.

19.7 How can the technology being disseminated be sustained?

A **sustainable extension process** should have the following characteristics:

- Be able to share knowledge and teach skills rather than just provide information.
- Be pluralistic in nature or allow for the participation of a multiplicity of service providers who can develop collaborative partnerships, based on their respective comparative advantage, between the private sector, NGOs, micro-credit, governmental, research, educational and extension agencies.
- Facilitate capacity building of tree nursery operators' (or farmers') associations and extension staff.
- Facilitate access and interpretation of market information.
- Enable participatory market chain analysis for tree seed and seedlings.
- Develop and promote self-sustaining extension programmes of tree seed and seedlings with cash-generating activities.

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