Trends in Tree Seed Systems in Ethiopia

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Ethiopian Institute of Agricultural Research

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Main photo: deciduous dry forest at Metema; top, left: camel browsing on leaves and pods of *Acacia*; top, right: *Cupressus* cones drying for extraction at the Forestry Research Center

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Contents

Preface

Afforestation/reforestation is one of the nation's ambitious development programs to address the problems, which entails national capability in tree reproduction and quality supply of tree seeds. There is also a need to satisfying local demands for forest products and diversifying export commodities by improving the utilization of non-timber products (such as gums, resins and bamboo) and timber products as well. The contribution of forestry to household food security can also be maximized through the domestication and introduction of high valued fruit and fodder trees into farmlands.

The afforestation and reforestation programs that took place in the country in the last three decades to meet such demands were not successful due to the use of seeds/seedlings of poor seed source and the existence of poor species-site matching. Therefore, there is a need for developing strong national capacity to satisfy the needs for forest seeds both quantitatively and qualitatively; and especially much has to be done with regard to quality. More emphasis should be given to indigenous tree species to improve and enhance restoration of degraded natural high forests. However, information on the flowering and fruiting phenology, seed physiology, seed biology, seed ecology, and seed handling of most of the indigenous species is not satisfactory. Research results on such areas have great importance in generating appropriate technologies and guidelines for future reforestation and afforestation programs. The sources from which the genetic material should be collected are in many instances in danger of disappearing or of being depleted because of increasing pressure on natural forests. Therefore, actions to protect and conserve sources of forest genetic variability are urgently required in order to meet, among other purposes, future needs of seed for tree plantings. Finally, to meet the need for plant material for various plantation programs in the country, a well-organized forest reproduction and seed handling system is of great necessity.

The Forestry Research Center (FRC) of Ethiopian Institute of Agricultural Research (EIAR) organized a workshop entitled "Workshop on Tree Seed System in Ethiopia" from June 21-22, 2010. The aims of the workshop were creating awareness on the importance of quality seed for successful plantations, imparting the necessary technical skills and knowledge in seed collection and handling, sharing research findings with stakeholders in the tree seed system and creating platform for synergy among various actors in the system.

On the workshop, papers were presented and group discussions were conducted on various issues related to tree seed system in Ethiopia. The Proceedings presents six papers on research and review works and includes outputs of discussion of three working groups. We are grateful to all the authors of the papers and to all workshop participants for the lively discussion and fruitful deliberation we had in the two-day workshop.

We hope that papers presented in this publication and the workshop outcomes will contribute to the knowledge generation and experience sharing processes in the research system in general and would stimulate further action in the tree seed system of the country.

Opening Speech

The Director of the Forestry Research Center of EIAR, Dr. Woldeyohanes Fantu welcomed all the workshop participants, introduced the objective of the workshop briefly, and invited Dr. Wubalem Tadesse, director of the Forestry Research Process of the Ethiopian Institute of Agricultural Research (EIAR), to make an opening speech.

In his opening remark, Dr. Wubalem welcomed all the workshop participants, and reminded that the forest resources of Ethiopia are vanishing at an alarming rate, as a result of agricultural land expansion, ever-increasing demand for fuel and construction wood stimulated by rapidly growing human and animal populations.

He pointed out that even if there are encouraging efforts towards ecosystem restoration, yet lots of works are remaining and deforestation is continuing with even more drastic consequences. Reversal of deforestation and reclaiming degraded land is an enormous challenge, which requires massive planting materials, which implies higher seed demand. Therefore, strengthening the national seed procurement capacity is of paramount importance.

Dr. Wubalem elaborated that success in the establishment and productivity of forest tree plantations was determined largely by the species used and the source of seed within species. The need to use the best-adapted source of seed was recognized in the early years. No matter how sophisticated the breeding techniques, the largest, cheapest, and fastest gains in forest trees improvement programs can be made by assuring the use of the proper species and seed sources.. The losses from using the wrong sources could be enormously disastrous. Hence, much efforts, and thought must be expended on seed sources.

Dr. Wubalem also underlined the fact that tree seed quality could be affected by any activity associated with seed source selection and management; seed collection, cleaning, drying, packaging and storage. In many countries, establishment of seed orchards is taken up as regular forestry activity as it guarantees reliable production and steady supply of quality seeds. Seeds from seed orchards have produced substantial genetic gain in terms of growth, tree form, adaptability, disease and pest resistance and wood qualities whenever the activity was taken up seriously with detailed knowledge about the genetics and reproductive biology of the species. Finally he urged participants to promote the establishment of seed orchards for the economically important tree species.

Overview of Forestry Research Center of Ethiopian Institute of Agricultural Research

Woldeyohanes Fantu

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Introduction

Realizing the need to undertake systematic and coordinated research in the agricultural sector, the Federal Government of Ethiopia reorganized the National Agricultural Research system and established Ethiopian Agricultural Research Organization (EARO) in June 1997 by Proclamation 1997; and the EARO has been given full-fledged mandate to reorganize agriculture related research institutes under its umbrella. By the same proclamation, the FRC and the WUARC had been transferred to EARO. Since then, FRC is a center responsible for generating, improving, co-coordinating, adapting technologies, and assisting forestry research activities in order to fulfill the current and long-term technology requirements of the country in areas of forestry sector.

Currently, Forestry Research Center has a vision to generate/shop technologies and provide improved forestry technologies to stakeholders with ultimate goal of increasing the contribution of forestry sector to national economy and welfare of Ethiopian people. In light of the above vision, Forestry Research Center conducts its research focusing specifically on characterization and utilization of non-timber forest products, rehabilitation of degraded lands, popularization of lesser-known timber species and provision of improved tree seeds for different organizations and private sectors who are engaged in forest development, utilization and management activities,/ programs. The center address the multifaceted issues of forestry in the country to meet the demand for fuel and construction wood, to contribute to the protection and environmental rehabilitation of the rapidly degrading forest resources and increase the production of forest products for the rural and industrial development needs of the country.

Duties of FRC

1. Undertake forestry research activities in accordance with the national agricultural research policies and strategies;
2. Undertake research programs under its own initiative according to research gaps identified in consultation with different stakeholders;
3. Procurement and distribution of improved tree seeds;
4. Offer laboratory and saw doctoring services;
5. Offer training and advisory services to farmers, students, forest enterprises, NGO's, private tree growers, and investors;
6. Conduct collaborative research with international, regional, and national research institutes and higher learning institutions.

Organizational Structure of FRC

It is well known that most of the research activities in the past were fragmented and lack coherency because of the institutional instability. Today, the organizational structure of the FRC aims at the supply of forestry technology sustainably, and consists of the following research case teams.

1. Plantation and Agroforestry
2. Natural Forest
3. Non-Timber Forest Products
4. Wood Products

Each research case team has identified its own research themes from which different mega-projects were developed in order to deliver complete information/technology when the project is terminated. The mega project development was based on team approach and aimed at enhancing the team/collaborative work among the researchers within FRC and other research and academic institutes. The following mega research projects were developed under each case team for the coming 3-5 years (2008-2013).

1. Plantation and Agroforestry Research Case Team

The following are the projects conducted by the plantation and agroforestry case team.

1.1 Rehabilitation and restoration of degraded lands in selected agroecological zones of Ethiopia

Objectives

To generate technologies and information that enhances the rehabilitation of degraded lands and thereby improving the economic, ecological, and social benefits at various levels.

Specific objectives

a. Select the best performing tree/shrub species and species mix on degraded lands.
b. Investigate the role of area closure and fostering trees in rehabilitation of degraded lands
c. Assess the impact of single and dual inoculation of bio-fertilizers on early growth performance of seedlings on degraded land

1.2 Agroforestry for rural livelihood improvement and natural resources management

The general objective of the project is to improve the livelihood of smallholder farmers while enhancing the management of natural resources through agroforestry interventions and practices in a sustainable manner.

Specific objectives

a) Evaluate and promote different agro forestry technologies for wood, feed, food, income generation, and soil management.
b) Identify, characterize and quantify the economic value of traditional agroforestry practices in the various agroecologies; assess and compare the social, economic, and ecological value of the major competing land uses within the agroforestry land use systems

1.3 Selection of superior provenances and enhancement of tree planting in Ethiopia

The general objective of this project is to promote plantations of high valued timer species in the country.

Specific objectives

a) Evaluate provenance effects on the performance of *Juniperus procera* at two growing regions
b) Evaluate the growth performance of provenances of *Pinus canariensis* and *P. pinea*

c) Identify methods which enhance seed production in *Grevillea robusta* stands

d) Evaluate the growth performance of *Eucalyptus viminalis, E. deglupta, Tectona grandis, Gmelina arborea,* and *Cordia alliodora* at different sites

e) Select superior provenances and evaluate progenies of *Cordia africana* and *Hagenia abyssinica*

2. Natural Forest Research Case Team

The research focci under the natural forest research case team are:

- rehabilitation of degraded natural forests
- characterize population dynamics, resource base extent, regeneration status and species composition
- modeling of forest cover change, climate change and tree growth
- Forest protection (fire, pests and disease)

These research components of the natural forest case team are conducted in Bonga natural forest; the project activities comprise the following research components:

2.1 Vegetation structure and population dynamics (Project component I)

Specific objectives

a) Describe vegetation structure and patterns of population dynamics in natural high forest in a temporal and special variation in relation to degree of forest disturbance

b) Assess the potential and diversity of soil seed bank in the same forest for enhancing natural regeneration

c) Determine natural regeneration status of major/dominant and endangered tree species

2.2 Land use and land cover change (Project component II)

Specific objectives

a) Describe spatial and temporal changes in forest cover

b) Determine the driving forces of changes in forest cover

c) Map the extent of forest cover

2.3 Phenology, seed testing and propagation (Project component III)

a) Specific objectives Describe the reproductive phenology of various tree species in high forests

b) Determine the relationship between phenology and climate variability
c) Develop and compile appropriate methods and techniques for seed testing and propagation for the tree species

2.4 Socio-economic values of forests (Project component IV)

Specific objectives

a) Document indigenous knowledge about forest and wood land utilization and management
b) Describe and determine the economical values and contribution of forests and forest products to the local community

2.5 Valuation of various forests and forest lands (Project component V)

Specific objectives

a) Valuate the indirect values of the forest and wood land using different techniques
b) Describe forest land values in terms of forest growth and its associated products
c) Develop forest land value index for determining forest land cost and taxation

2.6 Characterization of forest soil conditions (Project component VI)

Specific objectives

a) Quantify the storage of total soil C and N in disturbed and undisturbed forest ecosystems along elevation gradient in the high forest and woodlands.
b) Determine variability and status of available base and acid cations as well as available P and N of different soil types under disturbed and undisturbed forests along elevation gradient.
c) Establish the relationship between C and N storage, forest growth, density and diversity.
d) Determine the relationship between the total and available plant nutrient elements
e) Identify and characterize major soil types along the elevation gradient in forested landscape.

2.7 Forest growth and rainfall variability (Project component VII)

Specific objectives

a) Develop absolutely-dated tree-ring chronologies of various tree species for developing tree-ring chronologies for Ethiopia by accurate identification of annual ring boundaries.
b) Calibrate and verify the relationship between rainfall and tree ring width growth, and with it refine understanding of how rainfall variability is related to the growth of different tree.
c) Determine the growth of dominant and economically important tree species, and generate data sets for establishing forest growth models applicable to forest management and planning.

2.8 Carbon stock in forests and soils (Project component VIII)

Specific objectives

a) Estimate sequestered carbon stock in soils and above ground vegetation in natural high forests, plantation forests and agroforestry systems
b) Estimate the cost of stocked carbon sequestered in these land use systems

2.9 Pests and diseases of forests (Project component IX)

Specific objectives

a) Assess the abundance and diversity of pathogens on the tree species
b) Identify the kind of pathogen(s) that causes disease/ damage
c) Evaluate the magnitude of damage they cause

2.10 Developing management plan for sustainable forest resource utilization and environmental protection (Project component X)

Specific objectives

Develop different options for the sustainable management of forests that integrates carbon sequestration, timber production, biodiversity, and climate change adaptation and mitigation

3. Non -Timber Forest Products Research Case Team Research

The case team has the following research foci:

- Natural gum and resin
- High land and low land bamboo management and utilization
- Bio-energy
- Other non-timber forest products (medicinal, edible, etc. plants and products).

The non-timber forest products research case team has the following mega projects:

3.1 Bamboo management and utilization in selected districts of Ethiopia

The general objective of the project is to develop improved technologies for sustainable production and utilization of bamboo thereby contributing to environmental protection and food security of the country.

Specific objectives:

a) Study seed storage behavior of lowland and highland bamboo
b) Develop appropriate techniques for bamboo stand management
c) Evaluate suitability of Ethiopian bamboo for mat board production
d) Study performance of introduced bamboo species
e) Develop propagation techniques for highland and lowland bamboo
f) Develop an efficient micro-propagation and *In Vitro* regeneration protocol for bamboo
g) Identify the genetic variation among different provenances of Ethiopian highland bamboo
h) Develop bamboo culms drying and preservation techniques
i) Assess important pests and diseases attacking bamboo and develop control mechanism
j) Evaluate Ethiopian highland bamboo provenances and their performance under different site conditions

3.2 Developing technologies for improving sustainable management of natural gum and resin production from drylands of Ethiopia

The general objective of the project is to develop comprehensive packages of technologies and scientific knowledge that promote the sustainable management and utilization of natural gum and resin resources for enhanced contribution to livelihoods, poverty reduction, and national economy while at the same time maintaining ecological integrity.

Specific objectives

a) Map the overall resources base of the selected high value gum and resin bearing species using Remote Sensing and GIS technology
b) Assess the current population status (diversity) abundance, regeneration status, population structure) of the study species
c) Develop technology for effective propagation, field establishment and assess the flowering and fruiting phenology

d) Improve the stands through selection of best provenances with higher growth performance and gum and resin yield
e) Develop and adopt suitable tapping, product processing and handling techniques that improve gum and resin yield and quality
f) Investigate physicochemical characteristics of gum and resin from the study species and to promote value added processing of these commodities
g) Investigate the type of insect pests and diseases attacking gum-resin bearing species
h) Scaling up the obtained technologies to be used at wider scale

3.3 Economic Contribution of NTFPs to Rural Livelihood and National Economy of Ethiopia

Specific objectives

a) Describe and assess the operation and strategies of the existing market, the stakeholders involved in the market chain and their respective roles and benefits
b) Assess the impact of product quality, quantity, seasonality on marketability of products
c) Identify existing and potential local and international markets and traders and conditions to access these market

3.4 Bio- energy research project

The general objective of the project is to test adaptability and calorific value of fast growing tree species.

Current Workforce at FRC

Ocupación	PhD	Msc	Bsc	Diploma	Others
Researcher	8	19	10	-	-
Technical support	-	-	-	12	11
Administrative support	-	-	3	17	79

Research projects, implementing sites and status

1. Case Team: Plantation and Agroforestry

Research project	Component	Research sites	Status
Rehabilitation of degraded land	Selection of trees and shrubs and area closure for rehabilitation of degraded high land	Debre Birhan (Gosh Ager)	Site selected, seeds collected, seedling production started
	Selection of trees and shrubs and area closure for rehabilitation of degraded Mid altitude	West Shewa (Tokokutaye,Guder)	Site selected, seeds collected, seedling production started
	Selection of trees and shrubs and area closure for rehabilitation of degraded low lands	Arsi zone (Dodota Sire)	Site selected, seeds collected, seedling production started
	Effect of rhizobium and mycorrhizal inoculation on seedling performance on degraded lands	FRC Green house and laboratory and field trial in all rehabilitation trial sites	New
Agroforestry	Agroforestry technology evaluation and promotion for highland	Chilimo Catchments	Site selected, nursery established and seedling produced
	Agroforestry technology evaluation and promotion for mid highland	West Shewa (Tokokutaye, Guder)	Site selected, nursery established and seedling produced.
	Agroforestry technology evaluation and promotion for lowland	Arsi Negelle	Site selected, Awareness creation, training, etc.
	Integration of multipurpose tree species (MPTS) in the existing homestead (apple plots) in the central highlands	Sendafa, Chancho and Degem	5 variety of Apple introduced on farmers field, MPTS integrated.
	Examining the socioeconomic determinants of tree growing (technology adoption)	Central highlands (Chilimo, Sendafa, Chancho, Degem)	Checklists prepared, secondary information reviewed.
	Promotion of market oriented agroforestry technology	Chilimo catchments	3 variety of Apple promoted.
	Characterization of traditional agroforestry practices.	15 major agroecologies	New
Industrial plantations	Provenance effects on performance *of Juniperus procera* at Awi (Gojjam) and Kulumsa	Awi and Kulumsa	Result of early performance at Injibara published, data being collected at Kulumsa
	Evaluation of provenances of *Pinus canariensis* and *P. pinea*	Holetta, Aman and Wondo Genet	Data on survival and growth performance being collected

	Enhancement of seed production in *Grevillea robusta* stands	Bedele and Wondogenet	Data on flowering and seed production being collected
	Evaluate the growth performance of *Eucalyptus viminalis, E. deglupta, Tectona grandis, Gmelina arborea, Cordia alliodora* at different sites	To be selected	Seeds collected for some of the species and seedlings under production
	Selection of superior provenances and evaluate progenies of *Cordia africana* and *Hagenia abyssinica*	To be selected	So far seeds from nine provenances of *Cordia africana* and eight provenances of *Hagenia abyssinica* collected
	Evaluation and enhancement of seed stands	All FRC seed stands	Evaluation teams organized and ToR prepared

2. Case Team: Non-Timber Forest Products

Research Project	Component	Research sites	Status
Natural gum and resin	Survey of the population status (diversity, abundance and regeneration) of the target species	Benishangul Gumuz (Assosa)	performed
	Developing technologies for effective propagation and field establishment techniques and assess flowering and fruiting phenology of the study species	Metema (N. Gonder), Yabello,	Ongoing
	Tree improvement through selection of trees with high growth and yield	To be selected	To be started after 2 years.
	Developing and adopting suitable tapping, processing and handling techniques and to investigate the effect of tapping on the physiology of the tree	Metema and Yabelo	Ongoing
	Investigating of physico-chemical characteristics of gum and resin from study species	AAU and Ambo College of Agriculture	Ongoing
Bamboo	Developing propagation techniques for highland and lowland bamboo in Ethiopia	Tikur Inchini (for high land) and Assosa (for lowland)	Ongoing
	Evaluating bamboo for different end-uses: Mat Board	FPURC laboratory	Ongoing
	Assessment of bamboo insect pests and disease	Pawe and other sites will be selected	Ongoing
	Introduction and evaluation of bamboo species	Suitable plantation sites will be selected	10 species introduced,

		soon	seedlings produced or propagated.
	Effect of different storage conditions on germination and field emergence of *Oxytenathera abyssinica* seeds	Pawe	ongoing
Socioeconomic research on Bamboo and natural gums	Socioeconomic research on Bamboo and natural gum resources	Yabello/Borena, Tigray, Metema, Bahirdar, Hagere-Selam,	Base line qualitative data collected
Bio-energy	Biomass production for Fuelwood: Adaptation and elimination trial, Biomass and energy analysis	Werer, Awash	Species selected, seed collected
	Biodiesel (*Jatropha*, Palm and *Pongamia*): Introduction of germplasm, nursery and plantation management	Melkassa	some accessions *Jatropha* introduced

3. Case Team: Natural Forest

Research project	Component	Research sites	Status
Natural forest management	Bonga Natural Forest management (High forest)	Bonga Forest	Sites selected, experimental plots established, most of the data collected
	Borena woodland management	Borena woodland	Proposal developed

4. Case Team: Forest Products Utilization

Project	Component	Research sites	Status
Selected tree species utilization research project research project	Selected tree species utilization research project	FPURC	Ongoing
	Investigate the suitability of four *Eucalyptus* species for particleboard production	FPURC	Samples trees selected and logged.
	Effect of age and site on the quality of lumber of *Cupressus lusitanica*	FPURC	Laboratory analysis completed

Major Achievements of FRC over the last Five year

- In order to decrease the pressure on indigenous trees, alternative *Eucalyptus* species have been identified for production of lumber and construction wood
- New Tapping technique for *Bosewellia papyrifera* has been introduced from India and it was found that it decreased the labour requirement by 50%
- Various tree planting techniques in semi arid areas of the country have been released
- Popularization of *Moringa* have been carried out in Oromia, Amhara, Tigray, Southern Nations, Nationalities and Peoples Region
- A total of 7.7 tones of improved tree/shrub seed collected annually from about 60 tree species
- A total of 25 tree seed zones and 45 sub-zones were identified
- Tree seed zone map and a corresponding memoir prepared
- Several seed stands identified for about 60 indigenous and exotic tree species
- Young plantations of *Juniperus procera, Cordia africana, Podocarpus falcatus* and *Hagenia abyssinica* were established for seed production
- Introduction of high value fruit trees (Apple and Plum) to ~ 160 farmers in Chilimo, Dendi, Degem, and Sululuta areas has been successfully implemented
- Early growth performance of different provenance of *Juniperus procera* identified
- Storage behavior and nursery performance of *Prunus africana* has been identified.
- Growth and yield model for *Cupressus lusitanica* stand management and maximum yield prediction model were produced
- Tree ring laboratory for long-term climate change research and forest growth has been established.
- Climate change related researches, including drought history and human-climate- environmental interactions were published in peer reviewed journals.
- International relations for collaborative research project development and research capacity building have been established

Forest Tree Seed

Seed distribution is one of the services provided by the center. In line with improved tree seed provision, seed stands were established to promote availability of quality germplasm. Currently, there are 300 ha of seed stand and 310 ha of natural forest stands protected to serve as a seed source. Research activities conducted in tree seed and seedlings include:

- Seed germination test
- Studies on seed longevity and storage behavior
- Studies on optimum seed moisture content
- Effect of soil mixture on seedling growth
- Effect of shading on seedling growth

- Effect of amount and frequency of watering on seedling growth
- The effect of mycorrhiza on seedling growth
- Studies on optimum seedling size

Major Constraints and Challenges

Constraints

- High turnover of researcher staff in recent years
- Inadequate field vehicles
- Inadequate modern lab facility
- Inadequately equipped coordinating head office
- Inadequately organized sub- centers and permanent research stations
- Inadequate follow up of existing research sites

Challenges

- In Ethiopia, the forestry sector has had a history of institutional instability and lack of appreciation from public as well as private sectors
- The nature of research projects:- because of the long gestation period of forests, the forestry research results are hardly obtained in short term research periods
- Uncoordinated/fragmentation of research agendas
- Inadequate base line information on some of the forestry disciplines
- Reserved effort of researchers to materialize the newly implemented team approach concept

Evaluation of Tetrazolium Chloride and Hydrogen Peroxide for Quick Seed Viability Testing

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Introduction

Seed testing is an essential element of intensive seed management for afforestation program. It provides valuable information on the genetic and physiological quality of seeds.

There are two approaches for seed testing quick, indirect viability testing and slow, time consuming, direct germination tests (Bhodthipaks, 1994). With the current trend of increasing demand for seed testing and decreasing resources, rapid test for tree seed viability is promising.

Among rapid seed viability techniques, the hydrogen peroxide (H_2O_2) and tetrazolium chloride (2, 3, 5-triphenyl tetrazolium chloride) are simple and less expensive methods than other methods. In the former method, the hydrogen peroxide decomposes into water and oxygen when kept at ambient temperature. This oxygen speeds up the initiation of germination and subsequent processes (Schmidt, 2000).

In tetrazolium chloride test, when presoaked and incubated seed is treated with tetrazolium solution, the dehydrogenase enzyme in actively respiring areas of living tissues in the embryo and endosperm produces hydrogen ions, which in turn react with the colorless tetrazolium chloride to form stable, red-colored, triphenyl formazan which is insoluble in water (Bhodthipaks *et al.*,1994). The tetrazolium test is quick, accurate, and reliable technique for determining seed viability.

As part of quality control, a germination test is required to check the viability percentage whenever a seed lot is processed and monitored during storage in the seed bank, but most seeds may lose viability during germination test, especially the recalcitrant seeds.

The objective of the study was to identify better and quick seed viability testing techniques for those indigenous tree species whose seed viability is lost rapidly during germination, and to know the germination behavior of the tree seeds.

Materials and Methods

Seed collection

The seeds of indigenous tree species including *Ekebergia capensis, Podocarpus falcatus*, and *Prunus africana* were collected in 2005, and the seeds of *Syzygium guineense* and *Croton macrostachyus* were collected in 2006 from western part of the country (Bedele and Dembi) and transported to the Forestry Research Center.

Experiments and seed testing techniques

The seed testing experiment was conducted on four replications. Fifty seeds were used in each replicate.

H_2O_2 techniques

All the seeds were soaked in water for 24 hours. The seed was cut diagonally at the radicle end for *Ekebergia capensis*, *Croton macrostachyus* and *Prunus africana*. For *Podocarpus falcatus*, the tough seed coat was removed by seed crusher, and for the two *Syzygium* species, the outer seed thin testa was removed. To prevent desiccation, the cut, and de-coated seed was kept in water. The cut and de-coated seed sample of each replication was placed in a fresh solution of 1% H_2O_2 in a beaker in darkness at 20-25% for 7 days. The used H_2O_2 solution was discarded and replaced by the fresh solution every three days (Bhodthipuks *et al*., 1994).

Tetrazolium techniques

For all species, seeds had been moistened at 20 ^{0}C for 3-48 hours and the seed coat was removed. The de-coated intact seeds were immersed in a 1% tetrazolium (TZ) solution and incubated in darkness at 30-35 ^{0}C for 1-24 hours. Following the staining processes, treated seeds were washed and placed in moist filter paper in Petri dishes until their viability was evaluated.

Germination test

For all germination tests, sterilized sand was used in plastic boxes, and di-ionized water was added everyday in germination room. Counting was done at two days interval until no new germinant was recorded.

Statistical analysis

Results are presented in percentage of total seeds used in each treatment. Data were subjected to analysis of variance using SPSS 18.0 software. A one way ANOVA and Dunkan's multiple range tests were used to compare and separate means, respectively. All data were tested at $p < 0.05$ level.

Results

The three viability techniques revealed significant differences for all the investigated species (Table 1). However, the mean separation revealed that not all the treatments were significantly different from each other (Table 2).

Podocarpus falcatus

For *Podocarpus falcatus*, the tetrazolium test was significantly higher from the result of the germination test (*P=0.010*) but there was no significance difference between hydrogen peroxide techniques and the germination test (*P=0.081*).

Croton macrostachyus

Viability determined by tetrazolium chloride testing was significantly differing from the viability determined by the germination test (*P= 0.000*). But viability determined by hydrogen peroxide was not significantly different from viability determined by the germination test (*P= 0.163*); and the viability percentages in both tests were low.

Ekebergia capensis

For *Ekebergia capensis*, there was no significant difference between hydrogen peroxide technique and germination test (*P=0.690*). However, there was significant difference between tetrazolium test and the germination test (*P=0.001*).

Table 1. ANOVA for the three viability-testing techniques for the tree species

Species	Sources of variation	Sum of Squares	DF	Mean Square	F	P-value
Podocarpus falcatus	Between Techniques	552.67	2	276.33	5.33	0.030
	Within Techniques	467.00	9	51.89		
	Total	1019.67	11			
Croton macrostachyus	Between Techniques	15828.67	2	7914.33	1017.56	0.000
	Within Techniques	70.00	9	7.78		
	Total	15898.67	11			
Ekebergia capensis	Between Techniques	844.67	2	422.33	15.97	0.001
	Within Techniques	238.00	9	26.44		
	Total	1082.67	11			
Syzygium guineense var. *guineense*	Between Techniques	2976.00	2	1488.00	21.09	0.000
	Within Techniques	635.00	9	70.56		
	Total	3611.00	11			
Syzygium guineense var. *macrocarpum*	Between Techniques	5028.67	2	2514.33	25.23	0.000
	Within Techniques	897.00	9	99.67		
	Total	5925.67	11			
Prunus africana	Between Techniques	4708.67	2	2354.33	31.21	0.000
	Within Techniques	679.00	9	75.44		
	Total	5387.67	11			

Table 2. Mean seed viability of the six indigenous tree seeds from the three viability testing techniques

Viability testing techniques		*Podocarpus falcatus*	*Croton macrostachyus*	*Ekebergia capensis*	*Syzygium guineense var. guineense*	*Syzygium guineense var. macrocarpum*	*Prunus africana*
Germination test	Mean	63.0 [a]	1.5[a]	60.0[a]	64.5[a]	82.0[a]	70.5[a]
	SD	9.59	1	7.66	3.42	4.32	7.55
Tetrazolium test	Mean	79.5[b]	80.0[b]	78.5[b]	58.5[a]	86.5[a]	65.0[a]
	SD	1.92	4.32	3	13.99	16.6	11.61
Hydrogen peroxide test	Mean	73.0[a]	4.5[a]	61.5[a]	28.5[b]	41.0[b]	26.0[b]
	SD	7.75	1.92	3.42	2.08	2.16	5.89

***Note**: Same letter indicates no significant difference*

Syzygium guineense var. *guineense*

Viability determined by tetrazolium chloride testing was not significantly differing from viability determined by the germination test (*P=0.339*). While viability determined by the hydrogen peroxide technique was significantly different from viability determined by the germination test (*P= 0.000*). For this species, the seed was considered viable when the embryo, especially the critical part, stained red.

Syzygium guineense var. *macrocarpum*

Viability determined by tetrazolium test was not significantly differing with the result of the germination test (*P= 0.540*). While viability determined by the hydrogen test was significantly different from the result of the germination test (*P=0.000*).

Prunus africana

For *Prunus africana*, tetrazolium testing was effective and there was no significant difference with the germination testing (*P=0.394*). While hydrogen peroxide test was not effective for this species, and the difference from the germination test was highly significant *(P=0.000).*

Discussion

In tetrazolium testing, the staining pattern was used to interpret the viability of the seed while in hydrogen peroxide test; the radicle protrusion pattern was used for the interpretation.

For *Ekebergia capensis*, the viability percentage of the tetrazolium test was higher than the viability percentage determined by the germination test. This is because tetrazolium test was not impaired by dormancy, fungal infection, and chemical damage. The same was observed for *Croton macrostachyus* and *Podocarpus falcatus*. Therefore, tetrazolium test can equally work with the germination test for these three species. Girma Balcha and Blyth (2000) found that tetrazolium test could also be applicable to *Podocarpus falcatus*. In evaluation of the viability pattern for *Syzygium* species, the embryo was used for the interpretation rather than the endosperm. This is because of the fact that the endosperm could not show any staining pattern and in addition, the color of the endosperm was red only slightly. Therefore, tetrazolium test equally works for all of the six species.

In hydrogen peroxide technique, the radicle emerged visibly and abundantly for *Ekebergia capensis* and *Podocarpus falcatus*. However, in *Podocarpus falcatus*, the very high metabolic activities make the seed to rupture, and the embryo was clearly observed. According to Bhodthipuks *et al* (1994), Hydrogen peroxide test is also effective in testing viability for some tropical tree species, and he recommended that appropriate seed pretreatment technique is a prerequisite to overcome seed dormancy.

The germination result for *Croton macrostachyus* was very low while the viability determined by tetrazolium test was high. This might be due to seed dormancy. Comparison of tetrazolium and hydrogen peroxide techniques with the germination test in testing of seed viability for various indigenous tree seeds is given in Table 2.

Conclusion

Tetrazolium test was a more effective technique than hydrogen peroxide technique for a quick viability test both soon after the seed collection and during seed storage for all of the six species. In contrast, hydrogen peroxide technique was effective for only the two species: *Ekebergia capensis* and *Podocarpus falcatus*. The tetrazolium test needs less time and space to accomplish, and since the duration of the test was short, there was no microbial infection. Seeds showed higher level of stains in the tetrazolium testing than in germination testing. This is because of the fact that tetrazolium tests were not impaired by seed dormancy, fungal infection and chemical damage, but germination test did. Creating optimum condition in the laboratory during germination test together with the difficulty in the interpretation of the tetrazolium test are also the cause in the difference of the results but the latter will be improved by improving the skills to manipulate the results.

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Field Germination and Storage Behaviors of *Diospyros abyssinica* and *Bridelia micrantha*

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Introduction

Ethiopia is known to be one of the richest in bio-diversity, of which the share of indigenous trees and shrubs is the largest. However, the pressure on these forest plants has reached a very critical stage (EFAP, 1994). In addition to these, there is a critical shortage of knowledge about native trees, which in one-way or the other is an obstacle for their successful regeneration in the country. This may also be why the plantation programs had mostly been relying mainly on a few eucalypt and cypress, which accounts about 58 and 29%, respectively (Demel Teketay, 1996). This is almost monoculture, and the forgoing professional discussions suggest for diversification in the future plantation.

In line with these, many indigenous trees of the country are found in inaccessible areas. For-example in Yayu natural forest only, more than 150 indigenous tree species are found (Tadesse Woldemariam, 2003). But there is no information on the germination, storage, and seed type, wood property and etc.., of most of these trees. Such scant information on these species means their underutilization and on the other hand has contributed to the overutilization of few species like *Cordia africana*, *Juniperus procera* and *Podocarpus falcatus*. It is also impossible to design viable conservation strategy unless we have detail information on indigenous tree species.

Limited information on our indigenous trees and shrubs do not allow tree growers and developers to use native trees (Demel Teketay, 1996). Although promising results have been obtained by researchers at Forestry Research Center, Wondo Genet College of Forestry and Natural Resources, Addis Ababa University, Institute of Biodiversity Conservation on the seed ecology and biology, storage behavior and nursery techniques for many indigenous tree species, there is still huge gap in knowledge for majority of the native species. The current research was initiated to study the field germination and seed storage behavior of two economically and ecologically important indigenous tree species growing at the Yayu natural forest namely, *Diospyros abyssinica* and *Bridelia micrantha*.

Materials and Methods

Seed collection

Seeds were collected from trees grown at Yayu natural forest located in the South Western part of Ethiopia in Oromiya Regional State. Yayu natural forest is located at 580 km southwest of Addis Ababa. It is among the few Coffee Priority Forests of Ethiopia. This forest is currently registered as one of the two UNESCO Bio-reserve of Ethiopia.

B. micrantha and *D. abyssinica* are among the major priority and most preferred timber tree species at Yayu areas. According to the local communities and experts, both species have very hard and durable wood. They are suitable not only for construction but also for other utility like farm implements, fuel wood and other uses. According to Tadesse Woldemariam (2003), mainly *B. micrantha* has restricted distribution and more or less no regeneration was found when compared to the widely distributed *D. abyssinica*. The experiences of local farmers and studies made so far indicate that there is a need for study and integration of these species in the reforestation and afforestation programmes, which again demands thorough study of the various aspects of these species, for example, seed ecology.

Seeds for this study were collected from different matured individual trees which were on average 100 m apart from each other. The collected fresh seeds were then mixed to form one seed lot for each species. *D. abyssinica* seeds were safely transported to Forestry Research Centre for processing and storage, while *B. micrantha* seeds were processed at field and then brought to FRC and stored until the start of the experiments.

Seed purity analysis

The following formula was used to determine the purity of the fresh seed once it was transported to FRC seed laboratory.

$$\text{Purity \%} = \frac{Weight.of\ 'pure'\ seeds}{Total\ weight\ of\ original\ sample},$$

Weight determination

The procedure followed to determine number of seed in a kilo of seed was:

- A sample of pure seeds was separated for weight determination during purity testing
- It can be expressed as weight of 1000 seeds or number of seeds per gram or kg
- ISTA recommends 8 samples to be used in weight determination using the following formula:

$$\text{No of seeds/kg} = \frac{1{,}000{,}000}{weight\ of\ 1000\ seeds\ (in\ g)},$$

and by doing this, number of seed can be determined using a seed counter.

Moisture content of seeds (MC %)

Seed moisture content (MC%)involves oven drying, at 105 ^{0}C for 16 hours, a weighed amount of seeds to determine their MC % on a wet-weight or dry-weight basis as follows:

$$\text{MC\% (wet-weight basis)} = \left(\frac{W-Wo}{W}\right) * 100\ \%$$

$$\text{MC\% (oven dry-weight basis)} = \left(\frac{W-Wo}{W}\right) * 100\%$$

Where; W is original or fresh weight, and Wo is oven-dried weight of sample

Field germination test

The overall aim of this particular experiment component was to understand the response of seed once the tree shades. It was also believed to give clue on the ability of the species to regenerate naturally and to see the role of altitude, light and seed resting depth on the germination of the seeds and latter on the growth of the seedlings. Thus, four experimental plots were established in the Yayu natural forest to assess the above-mentioned characters of each species. Two plots were established at higher altitude approximately (2235 m) and other two plots at the lower altitude (1360 m), which of course were delineated based on the natural distribution of the species. In each altitude one plot was with a dense canopy cover and the other being open or with very light canopy cover. In each plot, seeds were sown in two ways. In the first case, 50 seeds of each species were sown with a normal sowing depth (2-3 times deeper than the size of the seed) while in the second one, the same number of seeds was sown on the surface of the soil, i.e. seeds were not buried in the soil. This makes the experiment factorial, with three factors being altitude, canopy closure and sowing depth each with two levels. The seeds were inspected every three months and those that germinated were counted and tagged to avoid double counting. The seeds were considered germinated when the plumule comes out (Demel Teketay, 1996). Germination percentage was calculated as the cumulative percentage of 60 days after sowing. Analysis of variation was carried out with SAS after the germination percentage data were arc sign transformed following the procedures in Demel Teketay (1996).

Seed storage

In order to study the seed storage behaviors of the species, seeds were kept in sealed plastic bags and stored at different storage environment namely, Mud house, Iron sheet, Cold room and Grass house for 14 months. One-hundredseeds were taken from each storage environments and tested for their viability via germination (sowing 25 seeds in four replications), and the process was repeated every two months. Seeds were placed in moist filter paper in a petridish and kept at room temperature. The seeds were inspected everyday and those germinated were counted and discarded to avoid double counting. The seeds were considered germinated when the radicle reached the size of the seed. Germination percentage was calculated as the cumulative percentage of 60 days after sowing. Analysis of variation was carried out with SAS after the germination percentage data were arc sign transformed.

Results and Discussion

Purity

Purity was found to be 98 and 99% for *B. micrantha* and *D. abyssinica*, respectively.

Seed wt

Number of seeds per kilogram was 5,011 and 5,360 *B. micrantha* and *D. abyssinica*, respectively, which indicate that they are medium-sized seeds.

Fresh germination

Fresh germination was relatively higher for *B. micrantha* and *D. abyssinica*, i.e.,78% and 82%, respectively at 12.5 and 13% MC.

Field germination

Fresh seeds of *B. micrantha* and *D. abyssinica* showed higher germination of 78 and 82%, respectively. However, seeds of *B. micrantha* did not germinate in all experimental plots. According to Skoglund (1992), most tropical tree species do not form persistent seed bank. Abeje Eshete (2002) had similar results for *Boswellia papyrifera* that there was an absolute absence of seeds. However, Demel Teketay (1996) found that seeds of *Acacia abyssinica* and *Croton macrostachyus* maintained their viability after four years of storage in the soil. In fact, the same author had also found that seeds of *Bersama abyssinica* and *Ekbergia capensis* could not maintain their viability after one year of storage in the soil. The present study indicates that *B. micrantha* may not form soil seed bank, as there was no single seed germination at field level in different treatments. Hence, it needs further study on how to enhance the natural regeneration of this particular species. On the contrary, the seeds of *D. abyssinica* germinated in all experimental plots. However, there was significant variation ($p < 0.0304$) at the two altitudes where the highest germination (23.7%) was obtained from seeds sown at higher altitude while the germination was only 13% at the lower altitude. The difference in the germination percentages at the two different altitudes, high (2235 m) and low (1360 m) could be attributed to the specific niche required for the germination and/or the variation in the mean daily temperatures, moisture availability, soil macro organisms, slope etc.., between the two experimental sites and need further investigation to know the specific reasons. According to the data from Ethiopian Meteorological Agency, Yayu forest area is hot and humid with mean minimum and maximum temperatures of 12.7 °C and 26.1^0C, respectively. The mean annual rainfall is 2,100 mm with the minimum and maximum being 1,400 and 3,000 mm, respectively, which might be affected by Altitude and latter on affect seed germination and establishment (Woldemariam Tadesse, 2003). Though seeds sown with a normal sowing depth (2-3 times deeper than the size of the seed) showed better germination compared to unburied seeds, treatment means from the different depth were not significantly different. Similarly, different canopy closures did not show significant variation on the germination percentages of seeds of *D. abyssinica*. Canopy closures are affected by either the gaps created in the forest or the density of trees in a given forest area. The nature of the microclimate created under closed canopy or canopy gaps determines the type of species that could grow, and it may determine the future species composition of a given forest (Whitmore, 1975). In this regard, *D. abyssinica* was found to establish very easily irrespective of the level of canopy closures, suggesting light/shade might not be the limiting factor for the germination of the seeds. The current results conform well to other similar studies elsewhere. For instance, most species studied by Leiberman *et al.* (1995) and Abayneh Derero *et al.* (2003) were found to grow both under dense canopy closures or in gaps. However, Abayneh Derero *et al.*

(2003) found more seedlings and saplings of *Cordia africana* and *Croton macrotachyus* in gaps indicating the importance of gaps for the regeneration of the two species, or these species are pioneer that need the creation of openings for their perpetuation in natural forests.

Storage

As indicated earlier, fresh seeds of both species had showed high germination percentage relatively at higher moisture content. However, once stored in the different environments and seeds taken to laboratory for germination test, seeds of *B. michrantha* did not germinate starting from the second germination test, i.e. after 2 months of collection indicating that seeds have lost their viability immediately. According to IPGRI/DFSC (1996) seeds that do not tolerate drying and lose their viability within short period of storage are said to be recalcitrant seeds. Although the current finding leads to conclude that seeds of *B. michrantha* could be categorized as recalcitrant, yet it will also be worth doing further study by storing the seeds of this species under sub-zero conditions in the cold room, which the current study did not take into account. On the contrary, a large variation in seed viability of *D. abyssinica* was observed between the four storage environments and the storage period. Seeds stored in cold room and grass house, for instance, have higher germination percentage (15-57% and 5-26%, respectively) than the iron sheet and mud house storage environmentsThis could be an indication for the difficulties in storing some of the indigenous tree species seed from moist forests at local level. The seeds stored at the cold room had a germination percentage of 57% at the 8th months of storage though at the second month, it was 30% and this could be due to some external factors in the lab, mainly fungus attack. However, germination started decreasing to 15% after the 14th month of storage. Seeds stored at the grass house have a maximum germination percentage of 26% at the fourth month and less than 10% on the 12th month and becomes 0% at the 14th month of storage. Though fluctuated too much, the highest germination percentages at the cold room could be attributed to the regulated temperatures of the storage environment; and the same was reported elsewhere (e.g. Holmes and Buszewez, 1958; IPGRI/DFSC 1996). The seeds stored at the Iron sheet have a germination percentage of 14% for the first two months and 0% for the rest of the experiment period. Seeds stored at the mud house similarly had a germination percentage of 14% for the first four months and about 2% and even less after six months. The low germination percentage obtained at the mud house and Iron sheet could be attributed to the fluctuating temperatures compared to cold room (Holmes and Buszewez, 1958; IPGRI/DFSC 1996).

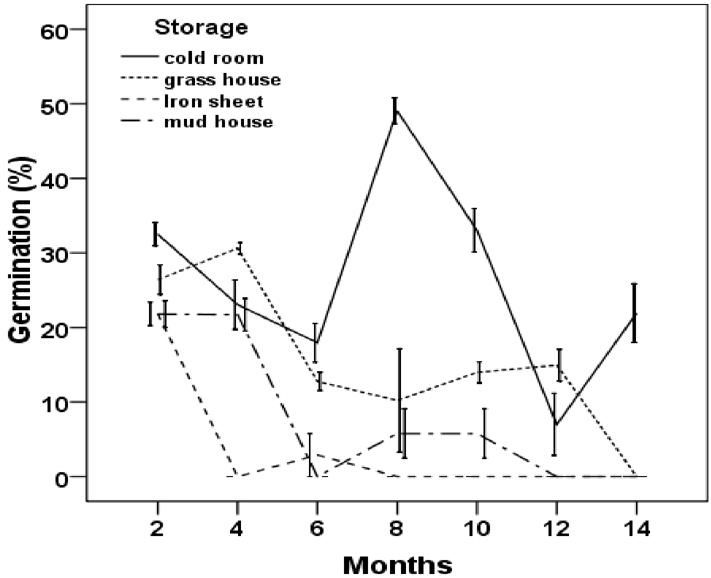

Figure 2. Germination percentage of *Diospyros abyssinica* seeds during storage at four different storage rooms for 14 months.

Conclusions

Based on both the current field germination and storage experiments, seeds of *B. michrantha* showed recalcitrant behavior and could not be stored for two months without decrease in germination percentage, in the currently available storage facilities, at Forestry Research Center. However, this needs further verification if seeds could be stored under sub-zero temperature. In any case, there is a need to look for other viable options to facilitate natural regeneration of the species and to store seeds for effective conservation and sustainable utilization of this very important and locally demanded tree species. Fluctuating temperatures of the storage environments affects the longevity of seeds of *D. abyssinica*. Seeds of *Diospyros* should be stored in cold room or grass houses where little or no fluctuation of temperatures is observed for somehow extended period. *Diospyros* showed higher germination performance at higher altitude seed while level of canopy closures and sowing depth are not the limiting factors for the successful germination of the species.

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Seed Handling and Optimizing Germination Performance of Tree Species: a review of existing techniques

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Introduction

Deforestation is the major environmental problem facing Ethiopia, and it has economic and social implications. Deforestation reaches 80,000 - 120,000 hectares per year (EFAP, 1994). The causes of deforestation are agricultural expansion, demand for timber, and fuel wood, poorly planned investments and resettlements for short-term benefits. The destruction and reduction of the forest areas affected the whole environment followed with massive and severe soil erosion and land degradation, which again resulted in poor crop production and famine. The loss of forests and other vegetation cover together with the recurrent drought and erratic rainfall have caused very serious problem to the people and to the nation as a whole. Nowadays tree planting activities for various purposes and products are increasing timber, fuel wood, construction, conservation, restoring the ecology and recreational purposes. Quality seed is essential for the success of such tree plantings. Seed should be matured, pure, viable, and free from diseases and pests and should be free from damage. Any activity in seed collection, handling, processing, and storage can affect the quality of the seed. Optimum storage condition and appropriate pretreatment techniques should be known to store seeds for a long time without losing their viability in the store and to hasten and effect germination of seeds of those tree species that develop dormancy and take a long time to germinate, respectively. Hence, efficient pretreatment techniques and appropriate medium should be identified for those tree species that have low germination percentage to enhance their germination.

Seed Quality

Seed quality has a direct impact on tree growth and the success of planting activities. It costs almost the same to establish a plantation from poor seed as it does from seed of high quality. However, the difference in the quality of plants produced and the economic returns can be vast. Therefore, the availability and use of quality seed is one of most important factor for the success of plantations and is responsible for higher economic returns and the growth performance of plantations. Seed quality comprises physical, physiological, and genetic quality. Any activity in seed collection, seed extraction, processing, cleaning, drying, and storage can affect the physical and physiological quality of tree seeds. Physical quality is seed quality related to physical characteristics such as size, color, age, seed coat condition, and occurrence of disease, pests, and other damage while physiological quality is related to physiological characteristics such as maturity, moisture content, or germination capacity. The FRC conduct seed quality tests before storage and distribution to customers. Viability of stored seeds is checked periodically so as not to distribute seeds which have showed a dramatic loss of viability. Moisture content test is performed by calculating the weight difference after moisture removal in an oven on initial weight base. Seed purity is analyzed by counting pure seed in a sample of about 800 seeds (in eight replications) that may contain chaffs, broken seeds and other impurities. Seed germination capacity is either determined by taking 100 seeds (in 4 or 5 replications) and sowing them in Petri dishes (for smaller sized seeds) or in containers filled with sand (for bigger sized seeds). However, sometimes ISTA rule, i.e. 400 seeds (in 4 replications) is followed if it is for research purpose.

Seed collection

Seed collection needs proper planning before collection activities precede. Seed should be collected at least from 30 individual superior mother trees that are separated from each other by 100 meters (Huber, 1993). It is advisable to examine the status of seed maturity before collection. Maturity can be assessed either by color, floatation or by cutting methods. Different tree species bear specific color when they mature. Mature and good seeds sink when they are put in water whereas hollow, empty, immature, or unhealthy seed can be identified when seeds are cut. Seed can be collected either from the forest floor, directly from trees or by climbing on trees. Even if seed collection from the forest floor is easy and inexpensive, it has a disadvantage that the seed may lose its viability due to excessive exposure to moisture and possible attack by diseases and pests. The seed collection practice of the FRC is mainly targeted to ensuring physiological quality in that mature fruits are collected while they are on tree branches. However, much remains to be done in ensuring genetic quality i.e. selecting plus trees for the purpose the tree species is principally grown and capturing variation by including several trees in the collection.

The experiences on seed collection in FRC include tree climbing (22 species), cutting branches/stripping off fruits (22 species), hand picking (10 species), shaking (8 species) and striking branches (4 species) (Table 1).

Seed processing

The objective of fruit or seed processing is to achieve clean, pure seeds of high physiological quality (germination capacity) which can be stored and easily handled during succeeding processes. Seed processing includes sorting, extraction, cleaning, and drying. Fruits, which are underdeveloped or infected with insects and diseases, should be discarded, and not fully matured fruit should be separated and allowed to after-ripen. Seed extraction is removal of seed from fruits and it includes activities such as drying and tumbling, de-winging, scrubbing, washing, and threshing. The extraction methods can vary with species according to the nature of their fruits and seeds.

After extraction, the seed lot may contain debris including empty seed and fragments of stems, leaves, fruit, wing, flesh, etc. To maintain high seed quality and viability during storage all debris must be discarded. This helps to avoid diseases and insect attacks during storage. Seed cleaning can be achieved by sieving, winnowing, de-winging and by liquid floatation methods. The fleshy seed or fruit should not be exposed to sun. Drying is preferably done under shelter and well-ventilated areas. Existing seed processing techniques used in the FRC for the various tree species include beating the fruit with light wood, threshing, soaking in cold water and crushing, sun-drying and sifting, macerating and washing and tumbling and cleaning with seed cleaner (Table 1).

Table 1 Seed collection and extraction techniques for the various tree species in FRC

No	Species	Seed collection technique	Seed extraction technique
1	*Acacia abyssinica*	Striking the branches/ pods with light pole	Beating with light wood
2	*Acacia mearnsii* (*A. decurrens*)	Shaking the trees	threshing
3	*Acacia melanoxlon*	Shaking the trees	threshing
4	*Acacia nilotica*	Shaking the branches	Beating with light wood / threshing
5	*Acacia saligna*	Shaking the branch/ tree	Beating with light wood
6	*Acacia senegal*	Striking the trees	Beating with light wood
7	*Acacia seyal*	Shaking the branches	Beating with light wood
8	*Acacia tortilis*	Shaking the branches/cutting down the branches with tree pruner	Beating with light wood
9	*Albizia grandibracteata*	Climbing and cutting down the branches	sun drying and beating with light wood
10	*Albizia gummifera*	Climbing and striking the branches	sun drying and beating with light wood
11	*Albizia schimperiana*	Climbing and striking the branches with light pole	Beating with light wood
12	*Azadirachta indica*	Climbing and picking by hand	Soaking in cold water for one day and crushing
13	*Cajanus cajan*	Picking by hand	sun drying and beating with light wood
14	*Callistemon citrinus*	Picking by hand/ cutting down the branches	sun drying and sifting
15	*Casuarina equisetifolia*	Climbing and cutting down the branches	sun drying and sifting
16	*Cordia africana*	cutting down the branches / climbing and picking by hand	Soaking in water for 3 days, abrasion/polishing and washing
17	*Croton macrostachyus*	Climbing and cutting down the branches/ picking by hand	Drying under cover
18	*Cupressus lusitanica*	Climbing and cutting down the branches / stripping off individual fruits	Sun drying and sieving
19	*Delonix regia*	Climbing and picking by hand	Sun drying and beating with a hammer
20	*Dovyalis caffra*	Shaking the tree	Soaking in water for 3 days, crushing and washing
21	*Ekebergia capensis*	Climbing and picking by hand	Soaking in water for 2 hrs and manual extraction
22	*Entada abyssininca*	Shaking the tree	Beating
23	*Eucalyptus camaldulensis*	Climbing and cutting down the branches	Sun drying, sieving, tumbling and cleaning with seed cleaner
24	*Eucalyptus citriodora*	Climbing and cutting down the branches	Sun drying, sieving, tumbling and cleaning with seed cleaner
25	*Eucalyptus globulus*	Climbing and cutting down the branches	Sun drying, sieving, tumbling and cleaning with seed cleaner
26	*Eucalyptus grandis*	Climbing and cutting down the branches	Sun drying, sieving, tumbling and cleaning with seed cleaner

No	Species	Seed collection technique	Seed extraction technique
27	*Eucalyptus saligna*	Climbing and cutting down the branches	Sun drying, sieving, tumbling and cleaning with seed cleaner
28	*Faidherbia albida*	Striking the branch/ pods with light pole	threshing
29	*Grevillea robusta*	Cutting down the branches	Sun drying and beating with hammer
30	*Hagenia abyssinica*	Climbing and strip off the fruit	Sun drying and crushing
31	*Jacaranda mimosifolia*	Stripping off individual fruits	Sun drying and beating with a hammer
32	*Juniperus procera*	Cutting down fruit bearing branches	Soaking in water for 3 days and abrasion
33	*Leucaena leucocephala*	Picking by hand	Beating with stick
34	*Melia azadarach*	Climbing and cutting down the branches	Soaking with water for 3 days and macerating
35	*Millettia ferruginea*	Stripping off individual pods	Sun drying and manual extraction
36	*Moringa stenopetala*	Climbing and picking with hand	Sun drying and manual extraction
37	*Olea europaea var. africana*	Climbing and stripping off the fruit	soaking in water for 3 days, macerating and washing
38	*Phoenix reclinata*	Cutting off the peduncle	Soaking, fermenting/ macerating and washing
39	*Pinus patula*	Climbing and stripping off individual fruits	Drying and shaking/tumbling
40	*Podocarpus falcatus*	Climbing and cutting down the branches/ stripping off individual fruits	Soaking in water, crushing and washing
41	*Prunus africana*	Cutting down the branches	Soaking for one day, macerating and washing
42	*Pterolobium stelatum*	Picking by hand	threshing, crushing in a mortar
43	*Sesbania aculeata*	Picking with hand	Beating with light wood
44	*Schinus molle*	Climbing and cutting down the branches	Sun drying for 1-3 days and polishing
45	*Spathodea nilotica*	Stripping off the pods	Sun drying till opening and manual extraction
46	*Syzygium guineense*	Climbing and stripping off the branches	Soaking in water for one day and manually extract

Seed Storage

Seed should be stored after processing until dispatching for various purposes. Seed storage behavior for the different species should be known to store seeds for a longer time without losing viability. Seeds are divided into three groups according to their physiological storage behavior (Schmidt, 2000). Orthodox seeds encompass seeds which can withstand drying up to low moisture content of about 5 to 10% and can be successfully stored at low or sub-freezing temperatures for long periods. Seeds of recalcitrant species cannot tolerate drying below relatively high moisture content (20-50% of fresh weight) and cannot be stored for long periods. A group of species which can be dried to a moisture content low enough to qualify as orthodox, but is sensitive to low temperatures typical for orthodox seeds has recently been termed 'intermediate' (Schmidt, 2000). At FRC, after moisture content testing and before seed drying, seeds are normally dried according to their preferable optimum moisture content for storage and stored in cold room at +5^{o}C. Generally, seeds can be stored well at consistent cool temperature, at low air humidity and moisture content and under dark and pest and disease free condition.

Standard seed pretreatment techniques

Seed pretreatments are methods applied to overcome seed dormancy to ensure rapid, uniform and timely seed germination that facilitates seedling production (Mulawarman *et al*., 2003). The emergence from dormancy is frequently regulated by a promoter-inhibitor system, where the principal promoter is gibberllic acid (GA_3) and the main inhibitor is abscissic acid (ABA). Low levels of inhibitor and high levels of promoter induce germination (Flores, 2002). However, dormancy in tropical and subtropical tree seeds is predominantly seed coat imposed (Smith et al, 2002). Various effective and practical treatments such as nicking, hot water soaking, and physical or acid scarification, have been developed to break dormancy. Appropriate pretreatment depends on the dormancy characteristics of the seed being treated. The common pretreatments are listed below.

Cold water treatment

Soaking in cool water is applied to overcome the physical, mechanical or chemical seed dormancy of some species e.g. Pine. Most often seeds are soaked in water for one day, but seeds of some species require soaking for two days (Mulawarman *et al*., 2003).

Hot water treatment

Soaking in hot water is applied to overcome the physical dormancy of seeds with hard, thick, and waxy seed coats. Water is boiled and removed from the source of heat and cooled for 10 minutes. Seeds are soaked in hot water while being stirred for 2-5 minutes, and then soaked in cool water for two days (Bisht and Ahlawat, 1999).

Boiling water treatment

Boiling water treatment applies to those species with very hard seed coat. Water is boiled and taken off from the oven, and immediately seeds are soaked for 2 to 3 minutes and removed (Mulawarman *et al*., 2003).

Mechanical scarification

Mechanical, or scarification, methods are used to overcome the physical and mechanical dormancy of hard and thick seed coats or fruit shells. Small holes are cut or scrapped in the seed coat or fruit shell with a knife, metal file or abrasive material to allow water absorption (Schimdt, 2000). After scarification, seeds are usually soaked in cool water for 1 day.

Wet and dry treatment or weathering

This pretreatment technique applies for those species with hard seed coat. Seeds will be soaked in cold water for 24 hours and dried in the sun (Mulawarman *et al*., 2003).

Acid scarification

This pretreatment technique applies for those tree species that have hard seed coat to break. Seeds will be soaked in concentrated sulfuric acid for one hour and then the acid is drained and the seeds are washed repeatedly with clean water (Sajeevukumar *et al*., 1995).

Stratification

Stratification involves keeping the seed at low temperature (1-5^{o}C) for 30-120 days. Alternating temperatures, treatments (like day and night) may also be required for some species. After stratification, seeds are immediately sown (Mulawarman *et al*., 2003).

Light treatment

Providing illuminated white light to the hydrated seeds can terminate dormancy of many tree species.

Hormones and chemicals

A number of chemicals (Thiourea and Hydrogen peroxide etc.) and hormones (Gibberellins, Cytokinins and Ethylene) in different concentrations can also be used to treat dormancy (Sajeevukumar *et al*., 1995).

Sound seed pretreatment, germination and storage practices

Seed pretreatment is essential for those tree species that develop dormancy before sowing both in the laboratory and in the nursery to facilitate their germination. In seed laboratory of FRC, seeds are sown in Petri dish using filter paper and in plastic box using sand as a medium. In Table 2, we presented existing seed pretreatments for various species in FRC and the resulting germination percentage. With the existing techniques, the overall mean germination of the 49 tree species was 45% (±24.68%). Therefore, we recommended new pretreatments and germination media to enhance and speed up germination of those species whose current germination percentages with the existing techniques were below 83%. It is estimated that with the application of the new pretreatment techniques a much higher (around 85%) overall germination performance can be obtained. The recommended pretreatments include chipping with scalpel and removing some structures and boiling and cold water treatments. The media of germination recommended mainly appears to be the use of agar; however, cost that may be incurred needs further investigation.

When it comes to storage, *Azadirachta indica* and *Ekebergia capensis* show intermediate and recalcitrant storage behavior, respectively, and require special handling. However, the majority (76%) of the tree species dealt with in FRC exhibit orthodox storage, and hence, they are easy to handle. Storage conditions with appropriate temperature and moisture content combination are suggested for all the species to ensure longer viability. Most of the species require hermetic storage (storage at airtight containers) (Table 2).

Table 2. Existing and recommended seed pretreatments

Species	Existing pretreatment technique	Germination %	Recommended pretreatment technique	Recommended germination medium	Expected germination with the new technique	Storage behavior	Storage condition
Acacia abyssinica	nicking	91	nicking	none	91	Orthodox	nd
Acacia mearnsii	nicking	77	scarification (removal of arils)	1% agar	98	Orthodox	hermetic storage at room temperature
Acacia melanoxylon	nicking	81	scarification (chipping with scalpel)	0.7 % agar	96	Orthodox	open storage at room temperature
Acacia nilotica	nicking	94	nicking	none	94	Orthodox	hermetic storage at room temperature
Acacia saligna	nicking	72	scarification (chipping with scalpel)	1% agar	96	Orthodox	hermetic storage at room temperature with 13+2% mc
Acacia Senegal	nicking	92	nicking	none	92	Orthodox	open storage at room temperature
Acacia seyal	nicking	89	scarification (chipping with scalpel)	1% agar	95	Orthodox	hermetic storage at 10°C with 4.5-9% mc
Acacia tortilis	nicking	88	scarification (chipping with scalpel)	1% agar	100	Orthodox	hermetic storage at 10°C with 4.5-9% mc
Albizia gummifera	nicking	74	scarification (chipping with scalpel)	1% agar	85	Orthodox	hermetic storage at 10°C with 6-10% mc
Azadirachta indica	none	44	scarification (removing the covering structure)	1% agar	77	Intermediate	open storage at room temperature at 11% mc for four months
Cajanus cajan	none	93	none	none	93	Orthodox	nd
Callistemon citrinus	none	99	none	0.7% agar	100	Orthodox	nd

Species	Existing pretreatment technique	Germination percentage	Recommended pretreatment technique	Recommended germination medium	Expected germination with the new technique	Storage behavior	Storage condition
Cordia africana	none	71	soak in cold water for 6 hours	1% agar	80	Orthodox?	hermetic storage at 3°C with 6-8% mc for at least one year
Croton macrostachyus	none	11	scarification (chipping with scalpel)	1% agar	75	Orthodox	nd
Cupressus lusitanica	Moist stratification	60	nd	nd	nd	Orthodox	hermetic storage at 3°C with 6-10% mc
Delonix regia	nicking	57	scarification (chipping with scalpel)	1% agar	89	Orthodox	hermetic storage at room temperature
Dodonaea angustifolia	none	19	seed scarified (chipped with scalpel); germination	1% agar	95	orthodox	nd
Dovyalis caffra	none	84	none	1% agar	95	Orthodox	hermetic storage at 3°C with 6-10% mc
Ekebergia capensis	Cold water treatment	33	nd	nd	nd	Recalcitrant	nd
Entada abyssinica	nicking	78	scarification (chipping with scalpel)	1% agar	100	Orthodox	nd
Erythrina brucei		57	boiling water for 5 seconds	none	90	Orthodox	hermetic storage at room temperature
Eucalyptus camaldulensis	none	76	none	1% agar	98	nd	nd
Eucalyptus citriodora	none	87	none	1% agar	90	Orthodox	hermetic storage at 4-6% mc and sub-zero temperatures
Eucalyptus globulus	none	93	none	none	93	Orthodox	hermetic storage at room temperature
Eucalyptus grandis	none	85	none	1% agar	95	Orthodox	hermetic storage at 3°C with 6-10% mc

Species	Existing pretreatment technique	Germination percentage	Recommended pretreatment technique	Recommended germination medium	Expected germination with the new technique	Storage behavior	Storage condition
Eucalyptus saligna	none	96	none	none	96	Orthodox	hermetic storage at 3°C with 6-10% mc
Eucalyptus viminalis	none	95	none	none	95	Orthodox	open storage at room temperature
Faidherbia albida	nicking	99	nicking	none	99	Orthodox	hermetic storage at 10°C with 6-10% mc
Grevillea robusta	none	83	none	none	83	Orthodox	hermetic air-dry storage at 3°C
Hagenia abyssinica	none	10	Removing the seed covering	none	86	Orthodox?	Hermetic air-dry storage at cool temperatures
Jacaranda mimosifolia	none	97	none	none	97	Orthodox	nd
Juniperus procera	none	43	seed removed after fruit soaked overnight in water	1% agar	75	Orthodox	hermetic storage at 3°C with 7-8% mc
Leucaena diversifolia		84	seed scarified (chipped with scalpel); germination	1% agar;	85	Orthodox	hermetic storage at room temperature with 5-8% mc
Leucaena leucocephala	nicking	91	nicking	none	91	Orthodox	open storage at room temperature
Maerua aethiopica	none	97	none	none	97	nd	nd
Melia azedarach	Sock in cold water for 3 days	68	Soak in cold water for 12 days	none	80	Orthodox	nd
Millettia ferruginea	none	84	none	none	83	nd	
Moringa stenopetala	Mechanical scarification	93	Mechanical scarification	none	93	Orthodox	nd
Olea europaea var. africana	Mechanical scarification	52	Scarification (removing the endocarp)	none	85	Orthodox	hermetic storage at 3°C with 6-10% mc
Species	Existing pretreatment technique	Germination percentage	Recommended pretreatment technique	Recommended germination medium	Expected germination with the new	Storage behavior	Storage condition

					technique		
Parkinsonia aculeata		91			91	Orthodox	hermetic storage at 3°C with 5-10% mc
Phoenix reclinata	none	94	none	none	94	Orthodox?	
Pinus patula	none	42	nd	nd	nd	Orthodox	hermetic storage at 3°C with 7-10% mc
Podocarpus falcatus	Mechanical scarification (removing the seed coat)	42	(de-coating)	agar	90	nd	nd
Prunus africana	nicking	42	Scarification (chipping with scalpel)	1% agar	70	Orthodox?	store moist (in sawdust at 37% mc) at 3°C
Schinus molle	none	86	none	none	86	Orthodox	hermetic storage at 10°C with 9-12% mc
Sesbania aculeata	none	65	hot water treatment	filer paper	100	Orthodox	nd
Spathodea nilotica	none	85	none	none	85	nd	nd
Tamarindus indica	none	46	scarification (chipping with scalpel)	1% agar	100	Orthodox	hermetic storage at 10°C with 7-15% mc
Ziziphus spina-christi		31	seed scarified (covering structure removed)	1% agar	90	Orthodox	hermetic air-dry storage at cool temperatures

Source: ICRAF agro-forestry tree database; Kew Seed Information Database; Laboratory test results at FRC and Abayneh Derero, 2004; nd = no data

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Toward a Tree Seed System that Guarantees Quality and Satisfies Demand in Ethiopia

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Introduction

Trees can be planted to produce wood for industry or for fuel wood, wood for charcoal, wood for domestic production, non-wood products, and environmental protection. Furthermore, trees can be planted to rehabilitate natural forests and deforested lands in order to restore productivity, biodiversity, and mitigating to climate change.

Vast areas of Ethiopia are degraded, and hence they need to be covered with vegetation so that rehabilitation takes place. For example, the already degraded 27 million ha of land in the Ethiopian highlands (FAO, 1984) needs immediate vegetation cover for its restoration as well as to stop further degradation.

Governmental organizations, regional state forest enterprises, numerous non-government organizations (NGOs), farmers, and communities throughout Ethiopia are involved with reforestation or other tree-planting activities. All of these groups can make important contributions to rehabilitating the degraded land in Ethiopia.

Recent reports of four Regional States (Oromia, Amhara, Southern Nations, Nationalities and Peoples and Tigray) claimed the annual planting of a total of over 3 billion tree seedlings in 2009 and 2010 (Derero et al., 2011). Planting of such a huge number of seedlings would cover 1.2 million hectare of land if planted at a spacing of 2500 trees/ha. Data on tree seed request and supply at FRC from 2007-2010 indicated that the center on average was supplying 7,278 kg of pure seeds annually in the stated period satisfying 78% of the request.

However, planting of over 3 billion seedlings would require much higher amount of seeds than what was distributed by FRC. An earlier report indicated that supplying 7.7 metric tons of seeds would give around 612 million seedlings (Derero, 2004). Thus, assuming that the species composition being planted has not changed much over the years, it is only 20 % of seedlings planted in the years 2009 and 2010 by the four Regional States whose seeds were obtained from FRC. In fact, this requires a further assumption that FRC distributed all of the seeds it collected entirely to these four Regional States, which might not be the case. This great disparity may indicate that the Regional States were getting seeds from their own collection and from other sources, in addition to the purchase from FRC. Otherwise, their reports of tree planting were highly exaggerated.

Indeed, besides satisfying quantity, seed quality is an important element that should not be overlooked as it determines the upper limits of yield and the productivity of labor, fertilizers, and other inputs (Cromwell et al. 1992) as well as enhance growth and productivity, particularly on degraded sites (Simons et al. 1994). Adequate quantities of seed can assure that planting targets can be achieved. However, adequate quantities of high quality tree seed often are not available in other parts of the world too (Roshetco et al, 2008). Often NGOs, farmer groups, many projects, and government offices involved in tree planting activities face shortage of tree seed of sufficient quantity and quality (Roshetko 2001).

The main plantation species in Ethiopia that are in high demand include *Eucalyptus globulus, E. camaldulensis, Acacia mearnsii (A. decurrens), Casuarina equisetifolia, Grevillea robusta* from exotics and *Cordia africana, Juniperus procera, Podocarpus falcatus* and *Acacia abyssinica* from the indigenous. The seed sources of these plantation species are mainly identified seed stands in natural forests and plantations (Derero, 2004).

Tree seed system

Seed production and distribution can be viewed as a seed system, which is composed of actors (organizations and individuals) having different roles and functions such as seed source establishment and management, seed processing, storage, distribution and marketing. A well-functioning seed system depends on good collaboration between the various actors (Kindt et al., 2006). The actors can be both from formal and informal sectors. The informal sector is made up of individual farm households, community based organizations (CBOs) as well as small-scale nursery owners and seed dealers, each carrying out their work on their own with little or no specialization. The formal sector is made up of public and private organizations with specialized roles in supplying seed (Kindt et al., 2006).

A centralized vs. a decentralized seed system

Within a centralized tree seed system, one institution collects, produces and distributes all tree seed. Within many tropical and subtropical countries, a National Tree Seed Center (NTSC) fulfils all these roles. 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 (Kindt et al., 2006).

In decentralized seed systems, many actors are involved in fulfilling the different roles 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.

The three major functions of actors in a seed system (i.e. ownership and management of seed sources, seed procurement, and seed distribution) can be linked in a centralized model or in a decentralized model (Table 1) (Graudal and Lillesø, 2007). In the table, the first letters in each model represent "seed sources," the second "procurement" and the last "distribution," and "C" stands for centralized and "D" stands for decentralized. The advantages and disadvantages of each of the various models depend on the seed source type. For example, collection of quality seed from natural forest sources can best be handled in centralized production and distribution model where collection of quality seeds from farmlands will be most efficiently handled by decentralized chains (Kindt et al., 2006).

Table 1 Seed supply models

Seed Supply Model	Example of operational seed supply systems
Centralized models	
CCC	Centralized government/large NGO model, e.g. many national tree seed programs
CDC	Contract worker or day laborer model, where only collection is outsourced
DCC	Centralized outgrower model, procurement done by distributor
DDC	Centralised outgrower model, procurement done by producer
Decentralized models	
DDD	Decentralized seed sources, decentralized enterprise model
DDD	Farmer to farmer diffusion model
CDD	Centralized seed sources, decentralized enterprise model

Source = Graudal and Lillesø, 2007; C= centralized, D= decentralized

Tree seed system in Ethiopia and elsewhere

The seed suppliers in Ethiopia currently are FRC, some private seed vendors and farmers. FRC has been the sole supplier of tested seeds and own several hectares of planted seed sources. Various offices of agriculture and some NGOs play a great role in seed distribution by conducting seed collection and/or buying from the seed suppliers and making the seeds available to farmers. In addition, these actors are involved in seedling production and distribution. Farmers also collect tree seeds and produce seedlings both for their own tree planting activities and for sale. In addition, efforts are underway to establishing Tree Seed Centers in some of the Regional States.

Analysis conducted during training on community based tree seed management in Goba in 2009 identified various actors and their respective roles in Arsi-Bale Ecoregion (Table 2) (Derero, 2009).

Elsewhere, a locally evolved system of seed collectors, seed assemblers, intermediaries and seed companies conducts seed procurement and diffusion activities. Farmers are active in tree seed collection, and their seed sources are state plantations and farmland. Farmers sell seed collected to companies and assemblers and local customers. The assemblers sell the seed-to-seed companies and intermediaries. Companies sell their seed to other companies or intermediaries, the remainder being sold to seed customers (government agencies, state companies, private companies, development projects, private nurseries, farmers, and NGOs). Intermediaries sell their seed to customers (Roshetco et al, 2008).

In another tree seed system, the majority of seed collectors consist of farmers/villagers, groups such as village natural resource management committees, or individuals. They collect seed for mainly own use or community use. Further, they occasionally collect on request or contract on more or less agreed rates by external buyers. A second group of collectors is professional, i.e.,being seed-collectors from organizations, particularly the tree seed center, collect special species themselves. Private seed dealers are absent in this system. Seed receivers are tree seedling producing nurseries at all levels. NGOs distribute seed to own and group-nurseries. The ultimate seed users are the same group as the collectors, namely the farmer group and a few other planters (Pedersen and Chirwa, 2005).

Table 2 Composition and functions of actors in tree seed system in Arsi Bale Ecoregion

Actors in seed collection	**Roles of actors**
Private collectors	Seed collection from farmers and trees, sell to users
Farmers	Seed collection, raise seedlings, sell extra seeds
Sinana Agricultural Research Center	Seeds of forage trees (collect, multiply and distribute)
Forestry Research Center	Seed collection, quality testing, seed distribution
Agricultural and rural development offices	Seed collection/purchasing, seed distribution, seedling production
Forest enterprises (Bale and West Arsi)	Seed collection, seed distribution, seedling production
Bale Eco-Region Sustainable Management (BERSMP)	Seed purchasing, seed distribution

Seed quality and seed sources

Attributes of quality seed

Generally, tree seed quality has to do with genetic quality of the tree species, physiological quality of the seed itself and species-site matching. Hence, quality seeds are seeds that match the planting site, that have been produced by out-crossing, collected from unrelated mother trees and seeds with inherited traits for good growth performance, shape and product quality. Furthermore, quality seeds show good germination ability, are free of pests and diseases, have high storability (Shmidt, 2004).

Tree seed sources and their phenology

Some of the actors in a tree seed system may be involved in identification, establishment, and management of seed sources, which are of various types.

In a given tree seed system, we may recognize different types of seed sources: identified seed stand, selected seed stand, selected single trees, seed production area and a seed orchard (OECD, 1974; Albrecht, 1993). The different seed source types represent different levels of tree improvement. An identified seed stand is a plantation, a natural forest or a farmland identified for seed collection. A selected seed stand is a natural or planted stand selected because of its outstanding quality, and is better than the identified seed stand. Selected single trees comprise of selected superior single trees as seed sources. A seed production area is a plus stand or a selected stand that is generally upgraded and opened by removal of undesirable trees, and then cultured for early and abundant seed production. A seed orchard is a plantation of genetically improved trees isolated to reduce pollination from genetically inferior outside sources and intensively managed to produce frequent, abundant and early harvested seed crops. The majority of seed collection of both indigenous and exotic tree species in Ethiopia is conducted from identified seed stands. Regardless of the seed source type, flowering and fruiting phenology plays the key role in planning seed collection.

Many tree species in the tropics have perfect flowers i.e. they have both male (staminate) and female (pistilate) organs in the same flower; examples in Ethiopia include *Cordia africana, Olea africana, Acacia abyssinica* from the native species and eucalypt, *Acacia mearnsii* (*A. decurrens*) and *Grevillea robusta* from the exotics. However, some other tree species have imperfect flowers i.e. they are unisexual; examples include *Podocarpus falcatus* and *Hagenia abyssinica* from indigenous species.

However, not all tree species have flowers. Tree species, which have flowers, are called angiosperms whereas those non-flowering plants are categorized as gymnosperms. Two of the native tree species in Ethiopia, *Juniperus procera* and *Podocarpus falcatus* are gymnosperms whereas the rest native tree species are angiosperms (Negash, 1995).

Tree species vary in their flowering and fruiting ages. In addition, tree species vary in their frequency of flowering; species such as eucalypt and several *Acacia* species flower every year whereas other species such as *Pinus patula* and *Boswellia papyrifera* flower every other year. The fruiting period of species such as *Juniperus procera* shows seasonal variation whereas species such as *Grevillea robusta, Podocarpus falcatus,* and *Olea africana* have mast years, (i.e. years with large seed production).

Provenance/progeny tests: a basis for seed orchard development

Provenance/progeny testing can be conducted for both indigenous and exotic tree species. The aims of provenance and progeny testing are selection of best adapted and best performing provenances and individuals, respectively. The provenance/progeny trial of indigenous species can be conducted within the seed zone the source is found or outside of the zone. However, the national research system should give priority to conducting such researches in forest poor areas. In fact, provenance/progeny trials are also relevant even in areas where local source is available since local source may not necessarily be the best performer. For example, the assessment of early performance of nine provenances of *Juniperus procera* indicated that the local provenance was one of the least performing provenances (Mamo and Mihretu, 2005).

Introduction and provenance/progeny research on economically important exotic species is highly vital, and this is one of the main responsibilities of research centers including seed centers. In 1975, FRC introduced seeds of various provenances of 50 tree species to Ethiopia. The species introduced included *Grevillea robusta*, 18 *Eucalyptus* species, two *Acacia* species, six *Pinus* species, three *Cupressus* species and three *Casuarina* species (Mihretu, 2006). Additional introduction and planting of various provenances of *Eucalyptus* species was made in 1987/88 making the total introduced eucalypt to be 70 different species (Davidson, 1995). In the year 1998, introduction and planting of two provenances of *Gmelina arborea* and three provenances of *Cordia alliodora* was made.

Seed and research centers should continue/embark on provenance/progeny trials quite aggressively, as these remain to be the basis for tree improvement and seed orchard development. Study conducted on ten provenances of *Eucalyptus saligna* revealed no significant differences in tree height, diameter, and volume and stem form (Hunde et al., 2003). However, stem form and branch diameters varied significantly among twelve provenances of *E. grandis* (Hunde et al., 2003). On the other hand, provenance/progeny trials conducted involving 300 families from 17 sub-races and one landrace of *E. globulus* and a progeny trial involving 405 families from a single provenance (Petford) of *E. camaldulensis* and two local-families revealed significant differences in performance (Hunde et al., 2007; Moges, 1997).

However, previous provenance researches have shortcomings in that they were conducted in single location. However, such researches should be conducted in multiple locations. If a provenance research reveals no significant difference in the planting zone, then it means one can use any or many provenances throughout the planting zone. If there exists large provenance difference but no genetic-environment (G x E) interaction, it means that one or few provenances are best, and these best ones should be deployed on all planting sites. However, if there are large provenance differences and large G x E interaction, then it means that best provenance depends on site, and hence we need to match provenance to edaphoclimatic conditions (White et al., 2007).

Satisfying demand and guaranteeing seed quality

Amount of tree seed that may be needed in Ethiopia

Ethiopia has 11% forest cover according to the recent definition of forest, which is land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these threshold. However, it does not include land that is predominantly under agricultural or urban land use (FAO, 2005; FAO 2010). If Ethiopia targets to bring its forest cover to the African average (23%) or the global average (31%) (FAO, 2010), and plants 2500 seedlings per ha, close to 33 to 55 billion seedlings would be needed. Hence, if there is national capacity and commitment to plant 3 billion seedlings annually and if deforestation is avoided, bringing Ethiopian forest cover to 23-31% would take 11-18 years of sustainable afforestation/reforestation program. Furthermore, additional high amount of seedlings is needed to increase tree cover in other lands. However, vast areas especially in *Acacia* woodland and dry montane areas may be rehabilitated with area exclosures, and hence there may be less need for seedlings.

Hence, tree seeds are needed to produce such amount of seedlings to increase the forest and tree cover in the country, diversify products and livelihoods, and rehabilitate degraded lands. Forest and tree harvests, the need to improve rehabilitation of degraded lands by fostering species, the need for planting economical important tree species in area exclosures and the need to replant failed afforestation and other tree plantings and the need to restore degraded forests make seed demand to be even higher and insatiable.

Proper seed calculation

Miscalculations of the amount of seed in seed requests can often inflate the gap between demand and supply of tree seeds. In addition, improper allocation of high amount of money than needed implies resource misuse. Seeds purchased in excess of the real needs would end up in damping or misuse of the seeds. Hence, seed suppliers should advise and help their customers to reach at the appropriate quantities for the targeted seedling production (Box 1). The customers usually may not have the proper information on the number of seeds per kg, purity, and germination percentages, which are essential to computing the amount of seed needed, and hence, they may come up with highly inflated seed requests. Furthermore, the germination potential of a species obtained in a seed lab does not usually be the same under nursery conditions. Rather there is a need to converting seed testing results to nursery production considering losses that may occur in the seed beds, during pricking out or transplanting, in the transplant beds and that some of the least vigorous surviving plants may be culled later at planting time. All of these factors together may make the number of plantable seedlings raised per unit weight of seed much less than the number of germinated seeds indicated by testing.

Box 1 Determination of the amount of seed required to prepare 1 million seedlings

Let us say we want to prepare seedlings of pines and eucalypts. A reduction factor of 20 % can be allowed for the difference between laboratory and field germination, a further reduction factor of 10 % can be made for pricking-out losses in pines and 15 % in eucalypts. Some additional 5 % allowance may be needed for later culling. The nursery recovery factor (i.e. seedlings which survive until planting in the field as a proportion of germinated seeds reported by test) then would be 65% for pine and 60% for eucalypt. If there is a plan of producing 1 million seedlings, then the following formula should be applied to compute the amount of seed needed.

$$\text{Amount of seeds needed (in Kg)} = \frac{\text{No of seedlings to be produced}}{\text{No of seeds per kg} * \text{Purity \%} * \text{Germination \%} * \text{Nursery recovery factor}}$$

Hence, the amount of *Pinus patula* seeds needed for producing 1 million seedlings assuming number of seeds per kg of 148,000, germination of 45%, and purity of 60 % and nursery recovery factor of 0.65 would be 38.5 kg. However, the amount of *Eucalyptus globulus* seeds needed for producing 1 million eucalypt seedlings assuming no of seeds per kg of 379,000, germination of 93, and purity of 80% and nursery recovery of factor of 0.60 would be only 5.9 kg.

Enhancing the participation of local communities in seed source management and seed collection

The development of a community based seed source management needs to be initiated. The local community can be involved in the process of seed source establishment, management and protection and can collect and sell seeds if the necessary support is given by Woreda offices of Agriculture. NGOs can play a significant role in assisting communities by organizing trainings and other support mechanisms. The Woreda office of agriculture can liaise between the seed centers and the community, and conduct monitoring of the seed sources, distribution of extension materials and conducting phenology surveys of priority species.

It is evident that to sustain community participation in the management of seed sources, the communities themselves must perceive clear benefits for their efforts. Seed collection and seed source protection should be incorporated within a broader range of forest related activities.

The marketing and distribution of seeds is crucial to the success of a community level seed supply system. Furthermore, quality assessment and certification of seeds entering the markets need to be given careful consideration. At the same time, it is necessary to encourage seed users to access good quality seeds through this system. The success of the system will largely depend on timely planning by the users so that orders can be placed according to the seeding times of the respective species.

The community can participate in establishment and management of seed sources. Experience in community forestry can be employed in this regard. There are already some activities concerning establishing community managed seed sources by some bureaus of agriculture. People participating in natural forest management where participatory forest management is being implemented and where state forest enterprises are active can make tree seeds additional sources of income. However, storage and market should be facilitated for the farmers to get interest in the business. Such activities should be supported by training, where research institutes like FRC and forestry schools would play a role.

Opportunities for private seed systems

Efficient seed supply is only likely to be achieved if considered as part of a commercial commodity chain in a market that encourages the operation of small and competitive seed vendors, and market distortions caused by free seed needs are avoided (Graudal and Lillesø, 2007).

The support of tree seed centers would be necessary, especially in the early stages of the establishment of private seed enterprises in clarification of matters related to seed source access, seed testing, and documentation.

Decentralizing seed supply

The Tree Seed Centers can identify and establish a number of seed sources throughout the country to be managed by offices of agriculture, but monitored and supervised by the centers themselves. Given the range of distribution of seed sources, there needs to be an organized system of marketing and distribution to link effectively the seed suppliers to the users, and one option would be to establish a national seed supply system.

In Ethiopia, decentralization with respect to tree seed system can be viewed in two ways. 1) Devolution of power to regional states and grass root level has given the regional states the constitutional right to establish their own institution, and hence some of the regional states have established agricultural research institutes, several research centers, state forest enterprises, and are in the process of establishing tree seed centers. Furthermore, the Ethiopian Institute of Agricultural Research, which is operating at the federal level, has several research centers. Woreda offices of agriculture are instrumental in all sorts of agricultural activity including agroforestry, forest development, and management. Hence, tree seed activity can be carried out at all levels if proper orientation, facility, and budget are rendered. Woreda offices of agriculture, state forest enterprises, and research centers can engage themselves in identification, establishment, and management of seed sources as well as seed collection and distribution of orthodox seeds. However, collection and distribution of seeds with recalcitrant and intermediate storage behavior should preferably be conducted with seed centers that have the necessary facility for handling of such problematic species. 2) As in other non-federal countries, several actors beside Tree Seed Centers can participate in the seed supply system. Seed vendors, private nurseries, farmers, community based organizations and NGOs can be capacitated to play a better role in the seed supply system.

Species specific seed supply system

Each tree seed species may require specific approach in the seed supply system. For example, several seed stands can be identified for the two common eucalypt species in Ethiopia (*E. globulus* and *E. camaldulensis*) from existing sources. Furthermore, farmers with access to the seeds can very much easily produce seedlings for their own both consumption and sale without much difficulty. However, farmers should be provided with improved germplasm of the two eucalypt for maximum productivity. On the other hand, for the highly demanded indigenous tree species such as *Juniperus procera, Hagenia abyssinica, Faidherbia albida, Cordia africana, Acacia abyssinica, Olea europaea* var. *africana, Acacia tortilis, Acacia nilotica, Acacia senegal* and *Podocarpus falcatus* as many seed stands as possible should be identified wherever there are sources. However, the seed distribution of these species should be limited in their seed zones assuming that local source is best unless proven otherwise. Regions that are suitable to grow this species but are devoid of local sources due to deforestation should introduce as many provenances as possible and carry out early selection for the short term and selection at mid rotation for the long run. The FRC should work closely with regional research institutes towards strengthening government and private organizations engaged in forest seed supply and forest development.

Conclusion

A single or few suppliers cannot satisfy the demand for seed quantity and quality. Rather, the active involvement of several actors in the seed system in a synergistic way would narrow the gap between seed demand and supply, and eventually satisfy it. Hence, understanding the modes of operations, linkages, and capacity of the various actors and working towards building capacity would improve the system.

Decentralized tree seed system can increase the seed supply many folds, and the demand for tree species whose sources are available can be fully satisfied. In this regard, measures to be taken to guarantee quality include seed source certification, setting the threshold for minimum number of trees to be included in the seed lot, germination testing at nursery level and deployment of the seeds within the seed zone similar to the source. Research should carry out provenance/progeny researches aggressively and lay the foundation for seed orchard development. Various research centers, Woreda offices of agriculture and state forest enterprises can engage themselves in seed source identification, establishment, and management as well as in collection and distribution of tree seeds of orthodox nature. Handling of tree seeds of recalcitrant and intermediate nature is best made by seed centers.

Farmers are the main actors in a decentralized system. Hence, all government bodies and NGOs should have a clear modality and system of working with farmers.

Tree seed centers should focus on developing seed production areas for those species to which there is shortage of seed source. They have to link themselves with various actors and ensure the flow of information in the system. They have to work to technically capacitating the other actors in the system. However, I think there is a need to have a separate overseeing body over all the seed centers (federal, regional) and other actors (research centers, Woreda offices of agriculture, state forest enterprises, NGOs) that ensures quality in the seed system. This independent body should work closely with relevant research institutes in monitoring and developing seed test standards and norms as well as issuing licenses following a standard procedure.

In general, a combination of centralized and decentralized tree seed system seems the best option to satisfy both quality and quantity. However, the advantages and disadvantages of the various combinations of centralized and decentralized organization depend on the type of the seed source. Actors in the seed system should discuss and devise strategy to ensuring quality and satisfying demands.

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Early Growth Performance of *Juniperus procera* and *Olea europaea* var. *africana* Seedlings under Three Soil Mixtures

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Introduction

Good seedling production depends to a large part on the growing medium used, i.e., the soil. A substrate (growing medium) should be light in weight to ease transport to the planting site, retain enough moisture to avoid need for frequent watering, porous enough for excess water to drain easily and allow sufficient aeration of the roots (Simons, 1999). In establishing plantations, it is necessary to produce high quality and large number of seedlings with less cost. Nursery technology that aims at the production of seedlings with good root system and healthy shoots under standard operations is necessary (Binkley, 1986). By taking care of seedlings until planting out makes them resilient to cope up with the harsh conditions at the planting site and compete with the existing vegetations. Among the standard operations exercised in nurseries, preparation of standard soil mixture is vital. Different nurseries have different standard soil mixtures. They are prepared to simulate forest soils, which provide the seedlings with good drainage (i.e., good water infiltration and holding capacity), good nutrient content, and mechanical support by holding the roots together. Appropriate soil mix generally makes the nursery pot suited for growth and in turn leads to high survival rate, i.e., minimal loss of seedling through death and damage (Binkley, 1986; Mailer, 1981). Forest soil, local soil, and manure are the usual components of nursery soil mixtures. Sand and compost are usual ingredients of soil mixtures in most nurseries in order to reduce the cost of using 100% forest soil, which is economically unacceptable in terms of transportation and depletion of the top forest soil. Sand is important in allowing the roots to have a good penetration, good water drainage and ease detachment of roots without damaging the roots. Compost provides the seedlings with nutrients and organic matter. Therefore, the standard soil mixture will provide the seedling with adequate drainage, proper aeration, adaptation to different soil types and good nutrient supply.

Most nurseries use mixtures of top soil with organic and inorganic additions. However, this does not always allow the development of a good fibrous root system. All nursery managers have their own favorite growth substrate. These vary depending on availability, but in developing countries they are mainly soil from agricultural or forest areas, sometimes mixed with sand/ or manure. When using it is advisable to do a chemical analysis on each batch, so that supplementary fertilizer can be applied if necessary. For any species, research is needed to find out the optimal substrate. When mixing, it is important that all components are finely ground and sieved through a 2 mm-sieve to remove excessively large particles (Simons, 1999).

Since different localities are characterized by different soil types and soil conditions that affects the growth of seedlings, it is important to investigate the proportions of the soil mixture for early growth performance of tree species seedlings. The objective of this experiment was to determine the best soil mixture proportion for the early growth performance of the seedlings of *Juniperus procera* and *Olea europaea var. africana*.

Material and Methods

Species Description

The species studied were *Juniperus procera* Endl. and *Olea europaea* var. *africana* (Mill). *J. procera* is a highly valuable timber tree found in the highland forests of Eastern Africa, extending from Ethiopia to Uganda. It does best in high rainfall areas but can survive in quite dry conditions once established. It performs well in Moist and Wet Weyna Dega and Dega agro climatic zones. It propagates through seedlings and wildlings. Seed germination rate is 20-60% and 40000-50000 seeds/kg (Negash Mamo *et.al.* 2006; Azene Bekele, 1993). *Olea europaea* var. *africana is* found in moist and dry highlands at altitudes between 1500 to 2500 m. It is extremely drought resistant and tolerant to frost. The wood is strong and durable (Husnia Ibrahim, 1984). If the soil conditions are favorable, seedlings of the species appear to be capable of developing deep root system. However, the roots of wild olive seedlings are sensitive to transplantation shocks (Legesse Negash, 1995; Azene Bekele, 1993).

Experimental site

The experiment was conducted at the nursery of the Forestry Research Center (FRC) from December 2009 to July 2009. The experiment site is located at $9^0 2$'N, $30^0 43$'E and 2400 m above sea level. It has a mean annual temperature of 22.5 ^{0}C and mean annual rainfall of 1225 mm.

Nursery experiment

For this experiment, *Juniperus procera* and *Olea europaea* var. *africana* seedlings were raised under different soil mixtures. The first soil mixture had ratios of 3:2:1 where 3 parts local soil, 2 parts manure and 1 part sand, the second had ratio of 3:2 where 3 parts local soil and 2 parts manure and the last was the local practice (control treatment) of 3:2:2 where 3 parts forest soil, 2 parts local soil and 2 parts sand. The local soil was obtained from the FRC, while forest soil was obtained from Menagesha-Suba state forest from underneath shrubs. The color of the forest soil was brown instead of the known dark color, which indicates the presence of well-decomposed organic matter. Local soil, forest soil, manure, and sand were mixed two or three of them at a time using manual shovel after drying and sieving with a 0.5 mm sieve. Each soil mixture ratios was filled in 150 pots and arranged in 18 plots in a completely randomized design of 25 pots/ plot. Four hundred and fifty plastic pots of 8 cm lay flat and 10 cm long were used. Two to three seeds were sown at a depth equal to the diameter of the seed in each pot. Only one seedling per pot was maintained for the growth experiment. Watering was done at every day at 9: 00 AM in the morning and at 4:30 PM in the afternoon, and the watering lasted for six to seven weeks. Root pruning was done at 180th day for *J. procera* and 201st day for *O. europaea* var. *africana*. The experiment was followed for 194 days. The height of seedlings of *J. procera* and *O. europaea* var. *africana* was measured at the age of 93, 114, 144, 174 and 86, 107, 137, 167, 194 days, respectively, after the seedlings had been transplanted. Analysis of variance (ANOVA) and mean separation were carried out in SPSS version 12 to test the effect of the soil mix on the growth of the seedlings and the differences between different species.

Results and Discussion

Height growth of seedling at specific point

The germination of seeds of *J. procera* and *O. europaea var. africana* completed at 40th and 15th days after sowing. The mean germination capacity was 33 and 34%, respectively. In *J. procera*, the seeds sown were untreated but in the case of *O. europaea var. africana* a pre-sowing treatment of socking in cold water for 24 hours was done. As shown in Figure 1, the best average height growth of both species was obtained in 3 parts local soil, 2 parts manure and 1 parts sand soil mixture (3:2:1 ratio). The smallest average height growth of both species was shown in 3 parts forest soil, 2 parts local soil and 2 parts sand (3:2:2); the result may indicate that the forest soil used was not rich in organic matter, because the part of the land where soil was taken was mostly open land and covered only with scattered shrubs.

The cost of mixtures used by other studies such as Legesse Negash (1995) to grow *J. procera* (mixture of sand, fertile soil, and animal dung (or compost) in a ratio of 1: 4: 3) can be reduced by using a mixture of 3 parts local soil and 2 parts manure as in the mixture of 3 part forest soil, 2 part local soil and 1 part sand. Local soils are important in soils mixtures to enhance early growth of seedlings, while at the same time they could minimize cost and create natural environment for better seedlings growth.

The soil mixture 3 part local soil, 2 part manure and 1 part sand as well as the soil mixture 3 part local soil and 2 part manure gave significantly higher ($p=0.002$) growth than the soil mixture 3 part forest soil, 2 part local soil and 2 part sand in *O. europaea var. africana*. However, the growth of seedlings of *J. procera* under the three-soil mixtures did not show any significant difference ($p>0.05$) (Figure 1).

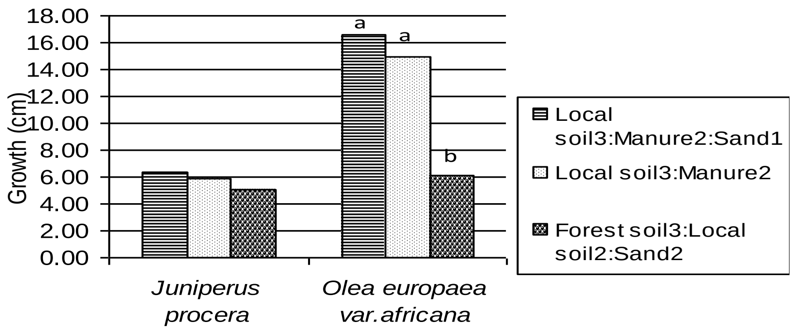

Figure 1. Height growth of seedlings of *Juniperus procera* and *Olea europaea* var. *africana* under three soil mixtures at around 28 weeks of age

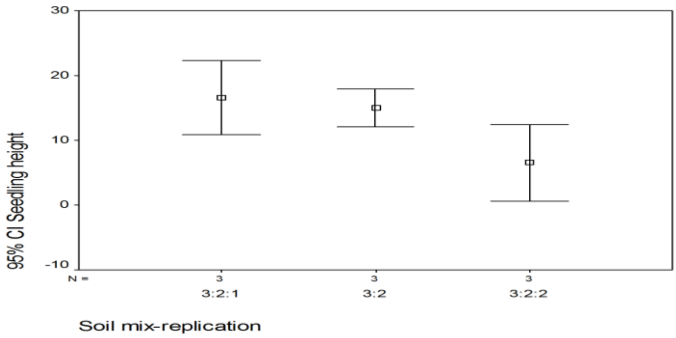

Figure 2 The effect of different soil mixture on the growth of *O. europaea var. africana* seedlings

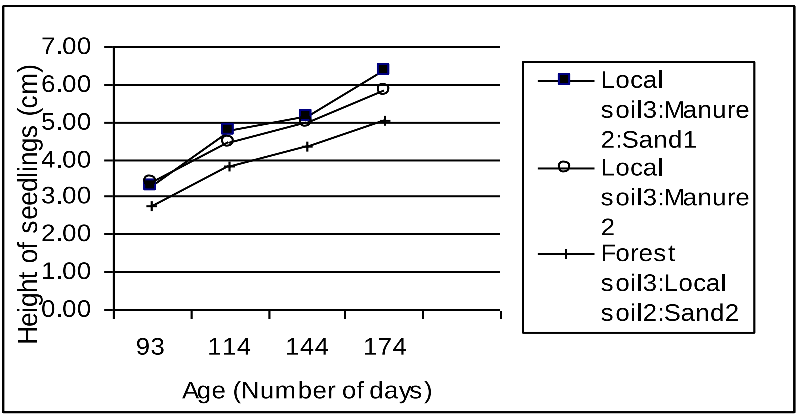

Figure 3. Effect of soil mixture ratios on the periodic growth of seedlings of *J.procera*

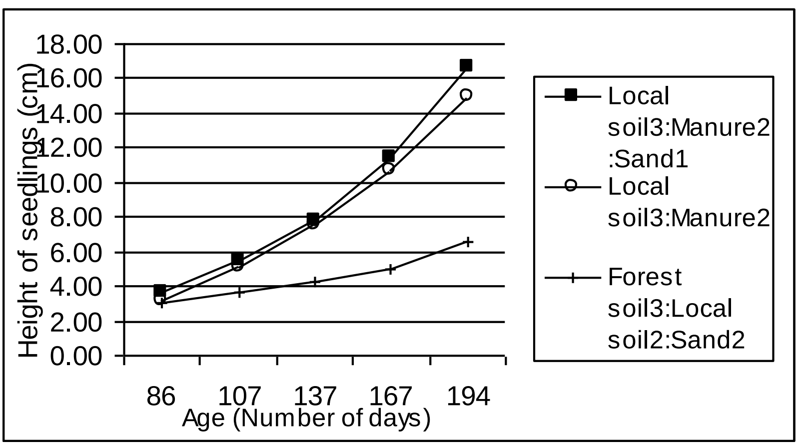

Figure 4. Effect of soil mixture ratios on the periodic growth of seedlings of *O. europaea var. africana*

Better mean growth was obtained in 3 parts local soil, 3 parts manure and 1 part sand which can be used for the nursery growth of *J. procera* in the central highlands where the soil is Vertisols. However, the growth of seedlings of *O. europaea* var. *africana* showed significant difference ($p = 0.002$) among the soil mixtures.

Mean separation among the treatments employing Tukey's HSD test indicated that the growth of *O. europaea* var. *africana* seedlings in the mixture that was constituted of forest soil, local soil and sand in the proportion of 3:2:2 was significantly lower than the growth in the other two soil mixtures, which did not give significantly different results between each other (Figure 1).

The diagrammatic presentation of standard error in Figure 2 also depicted that the commonly used soil mixture of the nursery site (3:2:2) showed poor growth of seedlings of *O. europaea* var. *africana*. Therefore, it may be not worthy to use forest soils of Menagesha Suba to uses as components of nursery soil mixture in Vertisols to grow *O. europaea* var. *africana* seedlings.

The study showed also that local soil, manure and sand mixtures were best growth media for better early growth of the seedlings. Additionally, cattle manure is purchased from the nearby area; the cost of acquiring forest soil, however, is more expensive than manure (personal communication with nursery workers). Since the nutrient content of the forest soil for nursery potting mixture was unknown, decision to use locally available manure or the so called forest soil was difficult. Therefore, nutrient analysis is a necessary step for decision making in obtaining nursery soil mixture.

Height growth trends of seedlings

The fastest growth rate of seedlings of the studied species was obtained at the third to fourth months after transplanting (Figure 3 and Figure 4). Both *J. procera* and *O. europaea var. africana* showed a very poor growth at control treatment throughout the experiment period (Figure 3). That is forest soils as component of soil mixture did not promote growth of the seedlings.

Conclusion

The seedlings grown under the soil taken from Menagesha-Suba forest showed inferior growth, and the reason needs further investigation. In the absence of well-decomposed forest soils, nursery soil mixtures should have manure. Therefore, it could be suggested that further studies of soil mixture at several sites and soil types would be necessary to draw general conclusion applicable for different tree species.

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Summary of Working Group Discussions

Participants were grouped into three working groups to deal with issues on tree seed sources, seed procurement, and seed research. The discussion points and the findings of the group discussions are given in Table 1 of this section. The outcomes of group activities are summarized as follows.

1. *List of potential actors in the formal and informal sector in tree seed system in Ethiopia and their roles in seed source ownership, seed source establishment and management*: An effort to list all potential actors in seed collection, distribution, test and storage resulted in a list of a total of 17 bodies. Furthermore, Forestry Research Center (FRC), Institute of Biodiversity (IBC), forest enterprises, associations established with participatory forest management, private seed suppliers, farmers, individual seed collectors, religious, academic and military institutions can play roles in seed source ownership, establishment and management.

2. *Pros and cons of centralized and decentralized seed systems in seed source management and seed procurement*: The centralized seed source management has the advantages that it can cover different agroecologies and can deal with nationally threatened species and avoid duplication of efforts. The centralized seed source management can be disadvantageous that it may not address specific demands and supervision can be difficult. However, seed source establishment and management in a decentralized system has its advantages that it increases sense of ownership, resources are quite accessible and close supervision is facilitated. The need for higher number of skilled manpower and the possibility of duplication of efforts can be disadvantages to the decentralized system. On the other hand, seed procurement in a centralized system has advantages in that it ensures supply of quality seeds, ensures known and well documented seed supply and it is easy for monitoring and evaluation. However, the centralized system has its disadvantages in that it may not ever satisfy demands and can become costly. Decentralized seed procurement on the other hand has several advantages and to mention few it improves participation of stakeholders, is less costly, creates higher employment opportunity and promotes business opportunities. However, in this system there can be difficulty in resolving possible conflicts of interest among stakeholders, seed quality may not be satisfactory and documentation may be poor or absent.

3. *Issues in partnership and networks among actors in the seed system to satisfying seed demands*: The establishment of a regulating central authority to improve networking among partners and enhance quality seed collection was suggested. In addition, there is a need to building capacity of partners and formulation of national strategies and policies on seed procurement. Further, identification of actors involved in seed procurement, identification of knowledge gaps in each actor in seed procurement, provision of training and technical support, organizing

farmers who are dealing with seed procurement, and establishing tree seed associations are essential. The Forestry Research Center for the short term can take the responsibility of networking and coordination within the tree seed system.

4. *Viable options for provision of quality seed with respect to the decentralized/centralized options*: The use of a combination of central and decentralized strategies happens to be a sound strategy. However, there is also a need for developing seed certification system and the Forestry research Center should capacitate and work together with seed suppliers and regional forest enterprises.

5. *Ways of creation of viable enterprises for seed production and distribution*: For establishment of viable enterprises, technical support should be provided from research and higher learning institutions, support should be provided in terms of offering sites for seed source establishment, improving financial capacities (credit scheme and tax exemption). However, there is a need for the establishment of certification system. Furthermore, a body that oversees and controls seed enterprises needs to be established.

6. *Potential of establishment of seed production areas, which represent dependable seed sources than identified seed stands*: Seed production areas on communally owned sources can be established by formulating agreements and making the community direct beneficiary. Seed production areas in natural forests can be established following proper agreements between the government institutions and involvement of the community; further forest enterprises can manage their own seed sources. There is also a need for setting objectives and criteria first, delineation of important seed sources and development of appropriate establishment techniques, guideline preparation and ensuring participation and partnership.

7. *Approaches for seed collection and distribution if seeds should be collected from all viable natural populations, taking Juniperus procera as a model species*: Seeds should be collected based on research findings (provenance trials). Seeds should be collected from best mother trees and from many trees within a given population. Seed collection should follow altitudinal gradients or seed zone, hence seed collection guideline should be prepared for the species, and information on planting site before seed distribution is needed. Furthermore, there is a need to filtering the existing Tree Seed Zones of Ethiopia, which is not species specific.

8. *Advantages and disadvantages of seed centers carrying out own collection or buying from farmers or community based organizations*: When seed centers carry out collection by their own staff, seed will be of higher quality and conflicts are avoided whereas the disadvantages can be the fact that seed supply is costly and there can be conflicts between centers and collectors. However, buying from farmers can be cheaper, quantity can better be satisfied, can encourage conservation and development of forests, and promote establishment of seed

supplier cooperatives. Disadvantages of buying from farmers may include that there is lack of guarantee for continuous supply of seeds, and it is highly likely that the seeds would be collected from genetically unknown sources.

9. *Type of technical research needed for sound and improved physiological, physical and genetic qualities of tree seeds*: Research on tree seeds should begin from gap identification and device ways for improvement of seed procurement activities. Tree improvement should focus on selection of best performing provenances in terms of yield and quality of fruits and seeds, wood quality, gum and resin yield, disease and drought resistance and in terms of water logging tolerance. Seed characterization (seed size, color, number of seeds/kg), tree characterization (tree form, branching habit, diameter, and height), phenological study (flowering, fruiting), and studies on disease and pest infestation should be given attention. Genetic marker based characterization, is also propagation, and stand establishment techniques, thus applicable seed pretreatment technology including indigenous knowledge should be researched on.

Finally, the plenary session discussed on the way forward. Seed certification in spite of who does it needs to be given attention. Actors in the seed system should have a regular forum to discuss on issues of common interest and share recent developments in seed science and technology. A strong forestry institution is vital to ensure the functioning of a viable tree seed system on the one hand and ensuring sustainable forest development in the country on the other.

Table 1 Findings of working group discussions

Issues/discussion points	Group reports on the discussion points and issues	
	Groups: seed source group/seed procurement group/seed research group	
Enumerate the potential actors in the formal and informal sector in Ethiopia and their roles seed source ownership, seed source establishment and management.	**Seed source group** • Potential actors in the formal sector: ○ it should be legal ○ should have the technical as well as the material competence to collect quality seed ○ Should have the potential to own the resource (or getting on contract agreement) • Formal sectors ○ Forestry Research Center ▪ The center owns different seed sources for various tree species ▪ Has adequate technical and material competence (Human and material resource) ○ IBC (Institute of Biodiversity) ▪ Can use and mange sites under *in situ* Conservation sites ○ Forest enterprises ▪ They have plantations that can be used as seed sources ▪ They have the management experience ▪ They have the management experience ○ Associations established with participatory forest management ▪ They have the potential to own and manage forest resources ○ Private seed suppliers	**Seed procurement group** 1. Forestry Research Center-collection, storage, test and distribution 2. Regional Bureau of Agriculture-collection, storage, test and distribution 3. Oromia forest and WL Enter-collection and distribution 4. Amhara forest and WL Enter- collection and distribution 5. Higher Learning Institutions-collection, storage and test 6. Eth. Natural Heritage Society- collection and distribution 7. Institute of Biodiversity- collection, storage, test and certification 8. Ethiopian seed agency- collection, storage, test and potentially also distribution 9. ILRI- collection, storage, test and distribution 10. World Vision -collection and distribution 11. Micro-enterprises- collection and distribution 12. Relief society of Tigray –potentially collection and distribution 13. ORDA -collection and distribution

	• Can fulfill all the requirements • Can establish their own seed sources o Associations established with participatory forest management • They have the potential to own and manage forest resources o Private seed suppliers • Can fulfill all the requirements • Can establish their own seed sources o Informal sectors o Farmers • Can preserve superior (plus) trees in their farmland and compound o Individual seed collectors • Can collect seeds from different parts of the country o Religious, academic and military institutions • They can achieve long-term conservations on threatened tree species	14. ODA- collection and distribution 15. TDA- collection and distribution 16. Cooperatives -collection and distribution 17. Private dealer- collection and distribution
Nearly all of the seed sources of indigenous tree species in Ethiopia are natural forests or farmland populations. We can identify suitable seed sources (**identified seed stand**) or select best stands against certain criteria (**selected seed stand**) or even manage the selected stands through thinning of inferior trees and improve the stand (**seed production area**). Can we	**Seed source group** Yes o Can be established by formulating agreements and giving appropriate incentives o This is possible on farmlands since it offers the farmers additional income o It should be done by involving the community in the mgmt o The community should be a direct beneficiary o On communally owned sources o An agreement can be made on tree resources under	**Seed research group** Yes o Objectives and criteria's should be set o Potential seed sources should be delineated o Appropriate establishment technique should be developed o Guide line preparation (% spacing, canopy closure, o Partnership involvement and participation o Superior provenance and progeny identification

establish such type of **seed production areas**? What should be done to establish such stands?	government institutions ○ Enterprises can manage their own seed sources	○ Establish seed stands/orchards with best provenances/progeny ○ Encourage tissue culture technology development
What are the pros and cons of centralized and decentralized seed systems in seed source management?	**Seed source group** ○ Centralized seed system ○ Advantages ▪ Seed sources can be established at different agroecologies of the country ▪ In addition to seed delivery, database on research findings could be established ▪ Nationally threatened species can get adequate emphasis ▪ It avoids duplication of efforts ○ Disadvantages ▪ May not address specific demands ▪ There is limited access to supervision ○ Decentralized ○ Advantages ▪ It creates feelings of ownership ▪ Access could be improved ▪ Facilitates close supervision and improve resource utilization ▪ It improves executing capacity of institutions at lower level ○ Disadvantages ▪ Requires high number of skilled personnel and adds costs ▪ May lead to duplication of efforts	**Seed procurement group** • Advantages of centralised ○ Promote quality seed supply (can be regulated) ○ Assure known and well documented seed supply ○ Easy for monitoring and evaluation ○ Minimize wastage (collection of matured seeds) ○ Appropriate for teaching and research ○ Easy for documentation • Disadvantage of centralised ○ Bureaucratic nature ○ Discourage privatisation ○ Can not satisfy demand ○ Costly • Advantages of decentralised ○ Improves participation of other stakeholders ○ Less costly ○ Encourage afforestation and conservation ○ Create employment opportunity ○ Revenue for government ○ Promote establishment of seed source areas

		○ Diversity increases ○ Knowledge transfer ○ Promote business opportunities • Disadvantage of decentralization ○ Control is difficult ○ Conflict among different stakeholders ○ Leads to corruption ○ Quality minimizes ○ Difficult for documentation
How can actors in the seed system be better partners and networked to satisfying seed demands?	**Seed source group** ○ A regulating central authority shall be established to improve networking among partners and enhance quality seed collection ▪ Building capacity of partners ▪ National consented strategies and policies should be formulated	**Seed research group** • Actors involved in seed procurement should be exhaustively identified (farmers, private seed suppliers, governmental and non governmental organizations, • Knowledge gaps should be identified in each actors seed procurement processes • Provision of training and technical support for seed suppliers (farmers, private supplier etc…) • Seed supplier should be either professional and/or working with professionals • Complement indigenous knowledge by scientific ones • Organize farmers dealing with seed procurement (forest dwellers) • Establish forest tree seed association to bring actors together • Networking and coordination with tree seed system established through FRC

			(Short term) • On the term basis forestry development institution should be established to handle the networking and coordination purpose
What strategy is a viable option for provision of **quality seed**; decentralized, centralized or a combination depending on the type of seed source? Any other recommendation?	**Seed source group** • The group suggested both central and decentralized strategies to be employed together • Tree seed centers, Agricultural Research Institutes, NGOs, Private Enterprises collecting seeds from their sites, and from CBO owned or farm land seed sources, and distributing by procuring at central place DCD (seed source-decentralized, Seed procurement-centralized, Seed distribution-decentralized)	**Seed procurement group** • At the moment combination of centralised and decentralised seed system is a viable option for satisfying demand and ensuring quality seed supply	**Seed research group** • Establish short, medium and long term strategy with alignment of tree seed system vision • The strategy should be a combination of two (decentralized + centralized) • Capacitate and work together with seed suppliers and regional forest enterprises • Seed certification system should be developed • The role of different actors in seed system should be clearly identified • Link has to be established with higher learning institution
How can viable enterprises be created for seed production and distribution?	**Seed source group** • Viable enterprises can be established – Certification system should be established – Technical support should be provided from research and higher learning institutions – Support should be provided in terms of • Offering sites for seed source establishment • Improving financial capacities (credit scheme and tax exemption)		**Seed procurement group** ○ establish nation a seed center that oversees and controls seed enterprises to be established elsewhere

Nearly all of the seed sources of indigenous tree species in Ethiopia are natural forests or farmland populations. Take *Juniperus procera* as model species: There may be 20 viable natural populations for *Juniperus procera* in the country. How best should seed collection and distribution be conducted if seeds should be collected from all the population?	**Seed procurement group** ○ Collect seeds based on research findings – ○ promote provenance trials ○ Selection of best mother trees from each provenance ○ Assess variability of trees both between and within population ○ Collection of seeds from many trees within the population ○ Filter the existing seed zonation	**Seed research group** ○ altitudinal gradients or seed zone based collection ○ Representative samples from each population should be taken ○ The seed collection areas and seed stands should be described ○ A seed collection guide line should be prepared ○ Seed testing and characterization ○ Species/provenance and site matching should be considered ○ Information on planting site before seed distribution is needed ○ Awareness creation and promotion
Tree seed centers can opt to establish their own seed sources or decide to collect or buy from farmers or community based organizations. What are the advantages and disadvantages of such an approach?	**Seed procurement group** Advantage from own source ○ Ownership is guaranteed ○ Closely managed ○ Enhance seed quality (plantation is established from improves stocks) ○ Avoid conflict ○ Ensure Continuous supply of seed ○ Encourage reforestation ○ Create employment and source of income ○ Aesthetic value and Ecological importance ○ Knowledge transfer in seed orchard management ○ Research and teaching importance ○ Promote networking with different institutions Disadvantage ○ Costly (establishment, management)	

	○ Conflict of interest with local community Advantage of buy or collect from farmers ○ Cheap ○ Encourage conservation and development of forests ○ Supply of seed in required quantity ○ Diversity increases ○ Contribute for livelihood improvement ○ Promote establishment of seed supplier and cooperatives ○ Self employment ○ Revenue for government Disadvantages of buy or collect from farmers ○ Lack of guarantee for continuous supply of seeds ○ Seeds are collected from unknown genetic source ○ Less management intervention ○ Interest of conflict on land use/ resource use
What technical research is needed on physiological and physical qualities of tree seeds? What technical research is needed on genetic quality of tree seed?	**Seed research group** ○ Gap identification and avoid duplication of efforts ○ Improve seed procurement activities (collection, handling, transport, and processing) ○ Tree improvement (selection of best performing provenances in terms of (seed/fruit yield and quality, wood quality, gum and resin, disease and drought resistant species, water logging tolerance) ○ Genetic engineering (marker based characterization) ○ Alternative propagation and stand establishment technique should be investigated ○ Alternative and applicable seed pretreatment technology (indigenous knowledge) should be researched ○ Characterize tree seeds (seed size, color, number of seeds/kg), ○ Phenological study (flowering, fruiting) ○ Disease and pest infestation ○ Tree characterization (tree form, branching habit, diameter, height)

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