Tree nursery and seed procurement characteristics influence on seedling quality in Oromia, Ethiopia

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\textbf{ABSTRACT}
Most tree nurseries in Ethiopia overemphasize mass seedling production to the expense of seedling quality. The study aimed at evaluating nursery characteristics and tree seed procurement approaches, and how these influenced seedling quality in eight purposively selected Woredas of Oromia region. A total of 169 respondents from government and non-government organizations, farmer nursery owners and development/extension agents and officers were interviewed. Seed quality was explored through assessing the seed supply sources, the type of seed source and mother tree selection, and the practices in seed physiological quality assessments. Our results revealed that over half (62.5\%) of the nurseries were government owned, while 20\% were NGO-run nurseries and the remaining 17.5\% were owned by farmers. Nine challenges constraining tree seedling production and leading to underperformance were identified, with the two major problems shared by all nursery types being lack of sufficient material and germplasm input and using seeds of low or unknown quality. Informal seed dealers were the main source of seeds (87.6\%) for all the nursery types. On the other hand, nursery operator’s own seed collection was from any free-standing trees either planted or retained as these sources were easily accessible. Seeds were, on average, collected from few mother trees, implying a high probability of sourcing seeds of narrow genetic diversity. Analysis of variance revealed statistically significant differences in seedling germination among the different seed procurement approaches within the same seed type. The seeds obtained from formal seed dealers had the highest germination rates in both hard-coated (87.3\%) and soft-coated (79.7\%) seeds. Our findings suggest that there is need to improve the seed procurement and the seedling supply system through quality assurance of the seeds used in seedling production.

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Introduction

Shortage of quality tree seeds has been a major constraint in afforestation, reforestation, agroforestry and related land restoration activities. Cognizant of this, tree seed programmes were initiated in many countries to mitigate the shortage in tree seeds. Graudal and Lillesø (2007) indicated that around 50 tree seed centres were established in tropical countries from 1960 to 2005. Many of the seed programmes opted for developing and identifying seed sources of various types, developing guidelines for seed transfers, embarking on tree improvement programmes, conducting capacity-building activities on tree seed technologies, and most importantly procurement and distribution of tested seeds in a centralized system. Though these programmes were quite instrumental in supplying quality seeds, they could not fully satisfy the demand for quality tree seeds that rose with increasing awareness on the importance of tree planting (Derero 2011). Alternative approaches to meet the demand developed which included self-collection of seeds by nursery operators and local seed exchange. Self-collection is the procedure by which nursery operators collect seeds from locally available trees for their use and/or for exchange with other nurseries. An informal, decentralized, seed supply system thus emerged to fill in the gap that was apparent from the formal sector’s inability to access the vast number of users in various geographical locations. Informal seed supply systems (both crops and trees) involve seed selection, production and dissemination. They operate mainly at the local level through exchange mechanisms and involve limited quantities per transaction, while formal seed supply systems are ruled by well-defined methodologies in seed production and supply (Wekundah 2012) and can transfer seeds over large areas (from local to sub-national and international level). Formal seed dealers are certified to supply quality seed, they carry out seed quality tests before dispatching and they ensure that supplied seeds are accompanied by the necessary information on seed source and seed quality. Informal suppliers usually distribute seeds with no formal test conducted and without any descriptive information (Roshetko et al. 2008). The importance of informal seed suppliers in tree seed distribution is increasing. In Kenya for example, nursery operators procure tree seeds predominantly from the informal seed supply systems (Muriuki 2005). In Indonesia, several seed companies are operational, with a group of seed suppliers in the Wonogiri–Ponorogo area controlling over 80% of the national tree seed supply capacity (Roshetko et al. 2008).

In Ethiopia, both the formal and informal tree seed systems operate in tandem. Formal seed supply began in 1975 with the establishment of the Forestry Research Center, which then strengthened seed supply activities by establishing the National Tree Seed Project from 1992 to 2002 (Derero 2004). The private sector (both licensed and informal) is fledgling in the country and is taking an increasing market share. Understanding the tree seed supply system, its functioning, its opportunities and challenges, is thus essential to identify leverage points and to ensure that quality tree seeds are delivered to users in the required amount. Failure to supply tree nurseries with good-quality seeds may even hamper the achievements of the strategic goals enlisted under forestry in the Climate Resilient Green Economy (CRGE) strategy of Ethiopia (FDRE 2011), and other related initiatives.

Quality seeds refer to seeds of high purity and germination capacity, collected from seed sources having good mother trees and processed, packed and distributed with the essential genetic, physical and physiological information (Nyoka et al. 2015). Good seed sources are those where a seed collector is able to get many mature trees that are good producers of
the desired product and free of diseases and insects. Provision of quality tree seeds therefore requires expertise in the field in addition to other physical and financial resources. Easy accessibility of the seed to the end users such as tree nurseries is also a very important attribute of a successful tree seed system, and this can only be achieved by a decentralized approach.

Tree nurseries can be established and operated by government agencies, individuals and groups, projects and non-government organizations (NGOs) to provide seedling for reforestation and community tree planting programmes, and to promote tree planting culture within target communities (Roshetko et al. 2010), which, in the context of most developing countries, usually consist of smallholder farmers. Farmers can also be engaged in tree seedling production to tap available markets and for their own consumption (Carandang et al. 2006; Gregorio et al. 2015) as individuals or in groups (Böhringer et al. 2003).

This study was conducted with seed dealers and nursery operators. Our objective was to assess tree nursery practices and seed procurement approaches in order to establish their influence on the quality of tree seedlings produced in selected Woredas (districts) of Oromia Regional State, Ethiopia. It was hypothesized that the seed procurement approach could significantly influence the resultant seedling quality. The paper proceeds by identifying and describing the problems, methods and purposes of tree seedling production. We then, compare the amount and quality of seeds supplied to nurseries through three seed procurement approaches (self-collection, formal and informal seed suppliers). Lastly, we try identifying the influence of seed procurement approaches and nursery types on the nursery performance of seedlings.

**Materials and methods**

**Description of the study site**

The nursery survey was undertaken in eight Woredas in two agro-ecological zones in the Oromia region of Ethiopia, in January–February 2014. The Woredas were selected to reflect the diversity in tree-crop systems, with a procedure explained in Iiyama et al. (2016). Four Woredas were located in a sub-humid area in East Wellega and West Shewa Administrative Zones and four in a semi-arid area in East Shewa Administrative Zone (Figure 1). Both areas

![Figure 1. Location of the study areas in Oromia region, Ethiopia.](image)
are located at mid to high elevation from 1600 to 3500 m a.s.l., with mean annual temperature ranging from 11 to 27 °C. The main difference between the two areas is the mean annual rainfall, which ranges from 200 to 1200 mm in the semi-arid area, and from 900 to 2600 mm in the sub-humid area (MOA 2007).

**Sampling**

A list of all nurseries, which had been producing seedlings of at least three tree species within the target Woredas in the two years before the study was obtained from the Agricultural Offices. The listed nurseries were then classified into three groups based on their ownership type, namely: farmer, government (GO), and NGO owned nurseries. Farmer nurseries are initiated and owned either by individuals or by a group of farmers, and usually get material support from NGOs and GOs. Government nurseries are owned and financed by the respective Woreda Office of Agriculture, and the source of the finance can either be regular or project based. Projects include national programmes such as the sustainable land management project and agricultural growth programmes, which run some nurseries separately from the other GO nurseries. Eventually, a total of 40 nurseries were identified: 19 nurseries from the sub-humid and 21 from the semi-arid areas (Table 1).

The respondents targeted for interviews included the people with direct and indirect involvement in seed procurement and tree seedling production: nursery staff (owners, foremen or employees) in the 40 nurseries, and GO and NGO forestry experts as well as development/extension agents for natural resources in the selected eight Woredas.

Both systematic and random sampling techniques were applied to select respondents. Since each of the 40 identified nurseries had a single foreman, they all were included in the list of the respondents. Similarly, since the nurseries were located in 38 different kebeles (the lowest administrative unit in Ethiopia), a natural resources development agent/extension worker from each kebele was included in the survey. In addition, a forestry or a natural resource management expert from each of the eight woredas and an additional expert working on a project were included in the list.

Furthermore, one expert from each of the six NGOs was also included in the survey. Additional respondents from the existing nursery employees were added randomly. To determine the sample size of the nursery employees, the following formula was used: \[ n = \frac{N}{1+N\epsilon^2} \] (where: \( n \) = Sample size; \( N \) = Total targeted population; \( \epsilon \) = Sampling error (0.06) or confidence interval at 94% (Zar 2010).

**Table 1.** Number of nurseries encountered in the different woredas and their ownership categories.

| Agroecology | Woreda                        | GO   | NGO | Farmer |
|------------|-------------------------------|------|-----|--------|
|            |                               | Regular | Project | Individual | Group |
| Sub-humid  | Jimma Arjo                    | 3    |     |         |
|            | Guto Gida                     | 4    |     |         |
|            | Gobu Seyo                     | 6    | 4   |         |
|            | Bako Tibe                     | 2    |     |         |
| Sem-arid   | Adami Tulu Jido Kombolcha     | 1    | 6   | 1      |
|            | Dugda                         | 1    | 2   |        |
|            | Bora                          | 2    |     | 1      |
|            | Lume                          | 2    |     |        |
| Sum        |                               | 21   | 4   | 8      |
|            | Proportion of nurseries by ownership type (%) | 62.5 | 20  | 17.5   |
Hence, a total of 169 respondents were interviewed of which 40 were nursery foremen, 76 nursery employees, 38 were development/extension agents, and the remaining were 9 GO experts and 6 NGO experts. The respondents were divided into two groups: key informants and other respondents. The key informants were 93 (i.e. the nursery foremen, the development agents, the experts, and owners of the two individual/farmer nurseries), and the other respondents were the 76 nursery employees, which were two from each of the 38 nurseries ran by GOs, NGOs and groups.

**Data collection**

Both qualitative and quantitative data were collected for the study from both primary and secondary sources. Primary data were collected through the use of structured questionnaires. Three types of questionnaires were prepared and administered: a main questionnaire to both respondent categories (key informants, and other respondents), and a specific questionnaire to each category. The questionnaires were tested and revised as appropriate before final implementation. The sources of secondary data were official/unofficial written documents including annual reports and different unpublished documents.

The main interview questionnaire focused on documenting nursery characteristics, list of species produced in each nursery, bottlenecks in seedling production and technical capacity. The specific questionnaire to the key informants focused on sources of tree seed, whether seeds were accompanied with sufficient information on the source and the handling techniques, and on the procedures followed to select seed suppliers. The specific questionnaire for the nursery employees dealt with the types of seed collected by themselves from local sources, the associated criteria for mother tree selection, and germination performance of the seeds in the nurseries. Generally, emphasis was given to assessing seed germination, which was defined as the capability of seed to produce normal germinant in nursery seed-beds, as evaluated by nursery staff. In addition, the seedling production capacity of the nurseries was estimated based on the number of nursery beds they normally allocate for bare-root and potted seedling production and the number of seedlings that could be produced on each nursery bed.

During data collection, three categories of seed suppliers were identified as: formal, informal and self-collection. The sole formal seed supplier then in Ethiopia was the Forestry Research Center that is located in Addis Ababa, and which distributes tested seeds with the necessary information. Informal seed dealers do not implement seed tests and their seeds are not accompanied by the required information. Self-collecting suppliers are nursery operators who themselves collect seeds from locally available trees.

**Data analysis**

Data were cleaned and entered into IBM SPSS Statistics version 20. Descriptive statistical tools were employed to analyse quantitative data such as the amount of seeds obtained through the three seed procurement approaches and the mean number of mother trees the seeds were collected from. All percentage values were square root arcsine transformed for all statistical analyses. Analysis of variance on seed germination was conducted in general linear model considering seed types and seed procurement approaches as fixed factors. Similar analysis was conducted on quantity of seedlings produced by each nursery.
considering mode of production (potted, bare-rooted) and nursery types as fixed factors. Least square difference (LSD) was employed to separate means.

**Results**

**Nursery types and seedling production**

The majority (62.5%) of the nurseries in the Woredas were government owned, whereas one-fifth of them (20%) were owned by NGOs and the remaining 17.5% by farmers (Table 1).

The nurseries produced both containerized (52.4%) and bare-rooted (47.6%) seedlings. Container seedling production was dominant in NGO nurseries, in which 91.3% of the seedlings produced were containerized and only 8.7% were bare-rooted. Bare-rooted seedling production was dominant in GO (61% of the seedlings) and in farmer (73% of the seedlings) nurseries.

The annual seedling production of each nursery varied from a mere 12 hundred to over half a million seedlings. The GOs and NGOs' seedling production was comparable, but farmer nurseries had significantly much lower production. The amount of potted and bare-rooted seedlings did not vary significantly among the three nursery types. However, the interaction between nursery type and mode of production was significant ($p < 0.01$) since GOs produced more of bare-rooted and NGOs more of potted seedlings (Table 2).

The major purpose of seedling production across all the nursery types was watershed protection, fodder production and wood production (Figure 2). Specifically, GO and NGO

| Nursery type | Mode of production | Mean   | SD    | N  |
|--------------|--------------------|--------|-------|----|
| GO           | Potted             | 68213  | 75011 | 25 |
|              | Bare-rooted        | 106693 | 124408| 25 |
| NGO          | Potted             | 173879 | 104742| 8  |
|              | Bare-rooted        | 16569  | 6375  | 8  |
| Farmer       | Potted             | 2728   | 1606  | 7  |
|              | Bare-rooted        | 7375   | 3114  | 7  |
| Mean         | Potted             | 77886  | 91630 | 40 |
|              | Bare-rooted        | 71287  | 108093| 40 |

**Table 2.** Estimated seedling production by nursery types and mode of production.

**Figure 2.** Proportions of seedlings produced for the different purposes in the eight woredas, Oromia region.

Other NTFP = non-timber forest products such as honey bee forage and medicinal plant parts.
nurseries produced seedlings mostly targeted for watershed management (soil and water conservation) and increased land production and productivity in support of the CRGE strategy, according to our key informants. Farmer nurseries produced tree species mainly for construction, shade and fuelwood since farmers’ demands for species with these end products and services was relatively higher.

**Nursery main problems and the challenges of seedling production**

The main challenges experienced by nursery operators are related to seed supply and good nursery practices. Nursery operators listed nine challenges constraining tree seedling production, with lack of sufficient material and germplasm input, and using seed of low or unknown quality as the two major ones across the three nursery types (Table 3). Water availability is also among the top constraints, especially for farmer nurseries. All the farmer nurseries also pointed out that availability of market for their seedlings is a challenge owing to the prevalent free distribution of seedlings by the other nurseries.

**Source of seed and procurement approaches**

The total number of species under production by all the nurseries in the study area was 40 (Table 4). The average number of species per nursery was six in the sub-humid and seven in the semi-arid sites (no significant difference). It was also found that all the nursery types in a given Woreda procured their seeds from the same seed dealers, which let the nurseries deal with more or less the same species in a given Woreda. Nursery operators, however, reported that they could not produce enough seedlings for some demanded species because they could not procure enough seeds.

All nursery types reported collecting seeds from trees available in their neighbourhood, in planted and natural forests, on farmland, and in any tree stand (Table 5). Most collectors reported collecting seeds from a few mother trees they know. They collected seeds from readily available sources (30.4%) and from trees with good appearance (29.2%), and some relied on their experience (24.4%). They gave little consideration to genetic quality nor to clear collection guidelines that could ensure quality of the harvested seeds. However, seeds of two fruit tree species, *Mangifera indica* and *Persea americana*, were collected from known varieties found in the nearby farmlands. The nurseries visited produce seedling of mango

| Major constraints                                                                 | Farmer nursery (n = 7) | GO nursery (n = 25) | NGO nursery (n = 8) | Total (n = 40) |
|-----------------------------------------------------------------------------------|------------------------|---------------------|---------------------|---------------|
| Lack of sufficient material and germplasm inputs                                  | 7                      | 25                  | 100                 | 100           |
| Using seed of unknown quality                                                    | 7                      | 25                  | 100                 | 39            |
| Water shortage                                                                    | 7                      | 10                  | 40                  | 25            |
| Low number of mother trees of target species for self-collections                | 1                      | 14.3               | 6                   | 24            |
| Damage by livestock                                                               | 4                      | 57.1               | 4                   | 16            |
| Damage by pests and disease                                                      | 2                      | 28.6               | 6                   | 24            |
| Client need unknown                                                              | 0                      | 0                   | 3                   | 12            |
| Low profitability of seedling business                                            | 7                      | 100                 | 0                   | 0             |
| Inadequate nursery space                                                         | 5                      | 71.4               | 0                   | 0             |

Table 3. Major constraints of seedling production in the selected nurseries in Oromia Region.
Nursery operators also buy seeds from formal and informal dealers. A comparison of the total weight of seed obtained through the three seed procurement approaches (self-collection, formal seed dealers and informal seed dealers) shows that, informal seed dealers provide the highest amount of seeds (87.6% of the total weight) and formal seed dealers supply the lowest amount (1.3% of the total weight) across the three nursery categories (Table 6).

Further, the key informants listed a number of indicators for what they perceive a good seed dealer should deliver. These included inexpensive seed (23.4%), supply in good time (23.4%) and avocado for direct planting unlike specialized fruit nurseries that rather use seeds only for producing root stocks for grafting purposes.

Table 4. Tree species in study area and proportion of nurseries producing them in the selected eight woredas in Oromia Region.

| No. | Name of Species       | Seed coat type | Sub-humid (n = 19) | Sem-iarid (n = 21) |
|-----|-----------------------|----------------|-------------------|-------------------|
|     |                       |                | Number | % | Number | % |
| 1   | Acacia abyssinica     | Hard           | 2      | 11 | 11     | 52 |
| 2   | Acacia decurrens      | Hard           | 9      | 47 | 0      | 0  |
| 3   | Acacia melanoxylon    | Hard           | 4      | 21 | 0      | 0  |
| 4   | Acacia saligna        | Hard           | 6      | 32 | 18     | 86 |
| 5   | Acacia senegal        | Hard           | 5      | 26 | 15     | 71 |
| 6   | Acacia seyal          | Hard           | 1      | 5  | 0      | 0  |
| 7   | Acacia tortilis       | Hard           | 1      | 5  | 17     | 81 |
| 8   | Albizia gummifera     | Hard           | 2      | 11 | 0      | 0  |
| 9   | Albizia lebeck        | Hard           | 0      | 0  | 1      | 5  |
| 10  | Azadirachta indica    | Soft           | 14     | 74 | 21     | 100|
| 11  | Casimiroa edulis      | Soft           | 0      | 0  | 1      | 5  |
| 12  | Cassia siamea         | Hard           | 0      | 0  | 8      | 38 |
| 13  | Casuarina equisetifolia| Soft           | 11     | 58 | 10     | 48 |
| 14  | Chamaecytisus proliferus| Hard          | 4      | 21 | 1      | 5  |
| 15  | Cordia africana       | Hard           | 7      | 37 | 6      | 29 |
| 16  | Croton macrostachyus  | Soft           | 2      | 11 | 3      | 14 |
| 17  | Cuppressus fusitanica | Soft           | 19     | 100| 19     | 90 |
| 18  | Delonix regia         | Hard           | 1      | 5  | 2      | 10 |
| 19  | Dodonaea viscosa      | Soft           | 1      | 5  | 1      | 5  |
| 20  | Dovyalis abyssinica   | Soft           | 10     | 53 | 20     | 95 |
| 21  | Ekebergia capensis    | Soft           | 1      | 5  | 0      | 0  |
| 22  | Erythrina brucei      | Soft           | 2      | 11 | 0      | 0  |
| 23  | Eucalyptus camaldulensis| Soft           | 13     | 68 | 11     | 52 |
| 24  | Eucalyptus globulus   | Soft           | 9      | 47 | 8      | 38 |
| 25  | Faidherbia albida     | Hard           | 5      | 26 | 13     | 62 |
| 26  | Grevillea robusta     | Soft           | 19     | 100| 21     | 100|
| 27  | Hagenia abyssinica    | Soft           | 7      | 37 | 0      | 0  |
| 28  | Jacaranda mimosifolia | Soft           | 11     | 58 | 12     | 57 |
| 29  | Jatropha curcas       | Soft           | 2      | 11 | 2      | 10 |
| 30  | Juniperus procera     | Soft           | 5      | 26 | 0      | 0  |
| 31  | Leucaena leucocephala | Hard           | 15     | 79 | 19     | 90 |
| 32  | Mangifera indica      | Hard           | 7      | 37 | 3      | 14 |
| 33  | Melia azedarach       | Hard           | 0      | 0  | 7      | 33 |
| 34  | Moringa stenopetala   | Soft           | 7      | 37 | 8      | 38 |
| 35  | Olea europaea         | Hard           | 3      | 16 | 1      | 5  |
| 36  | Persea americana      | Soft           | 3      | 16 | 4      | 19 |
| 37  | Podocarpus falcatus   | Hard           | 4      | 21 | 0      | 0  |
| 38  | Schinus molle         | Soft           | 8      | 42 | 13     | 62 |
| 39  | Sesbania sesban       | Hard           | 12     | 63 | 15     | 71 |
| 40  | Spathodea nilotica    | Soft           | 10     | 53 | 1      | 5  |

Mean number of species per nursery: 6.31.6 SE of the mean: 0.822 1.154

and avocado for direct planting unlike specialized fruit nurseries that rather use seeds only for producing root stocks for grafting purposes.
(22.5%), delivery at nursery site or Woreda office (19.5%), seeds with tag (13.4%), consistent supply (9.5%), licensed seed dealer (8.7%) and collecting from known seed sources (3%).

The seed quality, both genetic and physiological, was not of high priority to most of the key informants when procuring seeds. Key informants attributed this mainly to low financial capacity of farmer nurseries (individual, group) to purchase seeds of high quality, and to buy low-cost seeds by government-owned nurseries. The fact stated by key informants was that most GO and NGO nurseries also bought seeds mainly from the informal suppliers because of financial systems and bidding procedures which favoured low-cost purchase, and often the formal supplier may not be involved in the bids.

### Germination of seeds as evaluated by nursery operators

Seeds from some species such as *Grevillea robusta* and *Hagenia abyssinica* have soft outer cover, short storage time and germinate without treatment (soft-coated). Other species such as *Acacia decurrens* and *Acacia saligna* have seeds with a hard outer cover which usually exhibit dormancy and can be stored for a long time (hard-coated). Generally, hard-coated seeds had higher germination percentage (79%) than soft-coated seeds (65.4%).

### Table 5. Sources of seed and the main reason for procuring seeds from them in the selected eight woredas in Oromia Region.

| Sources and reasons | Sub-humid | Semiarid | Total |
|---------------------|-----------|----------|-------|
|                     | Res. (n = 38) | Res. (n = 40) | Total (n = 78) |
| Source of Seed      |            |          |       |
| Any tree stand      | 35 (92.1%) | 40 (100) | 75 (96.2%) |
| Planted forest      | 25 (65.8%) | 36 (90)  | 61 (78.2%) |
| Natural forest      | 13 (34.2%) | 9 (22.5) | 22 (28.2%) |
| Farmland            | 6 (15.8%)  | 4 (10)   | 10 (12.8%) |
| Main reason for collecting from such seed sources | Easy access | Only available | Good quality | Most inexpensive |
|                     | 29 (76.3%) | 30 (75)  | 59 (75.6%) |
|                     | 11 (28.9%) | 13 (32.5) | 24 (30.8%) |
|                     | 9 (23.7)   | 12 (30)  | 21 (26.9%) |
|                     | 4 (10.5)   | 6 (15)   | 10 (12.8%) |

Note: Res. = respondents (76 nursery employees and two owners of farmer nurseries).

### Table 6. Comparison of the weight of seed obtained by nurseries from three seed procurement types in the selected eight woredas in Oromia Region.

| No of types          | Seed procurement       | Weight of seed supplied to nurseries |
|----------------------|------------------------|--------------------------------------|
|                      |                        | kg (%) ± S.E.                        |
| Farmer nurseries (n = 7) | Informal seed dealer | 297 (94.2)c ± 0.503                  |
|                      | Self-collection        | 15 (4.8)b ± 0.43                     |
|                      | Formal seed dealer     | 3 (1)a ± 0.005                       |
| GO nurseries (n = 25) | Informal seed dealer   | 1320 (91.4)c ± 0.681                 |
|                      | Self-collection        | 111 (7.6)b ± 0.591                   |
|                      | Formal seed dealer     | 11 (1)a ± 0.103                      |
| NGO nurseries (n = 8) | Informal seed dealer   | 480 (75.3)c ± 1.24                   |
|                      | Self-collection        | 140 (22)b ± 1.002                    |
|                      | Formal seed dealer     | 17 (2.7)a ± 0.232                    |
| Total mean (n = 40)  | Informal seed dealer   | 2097 (87.6)c ± 0.78                  |
|                      | Self-collection        | 266 (11.1)b ± 0.598                  |
|                      | Formal seed dealer     | 31 (1.3)a ± 0.088                    |

Notes: n-numbers of sampled nurseries, and a, b, c show difference among explanatory variable at 5% significance level and a<b<c.
It was hypothesized that the seed supplier category would have some influence on seed germination rate and it was the case: there is a significant difference \((p < 0.05)\) in germination rate between seeds of the same seed type supplied by different seed procurement approaches. Seeds obtained from formal seed dealers had the highest germination rate for both hard-coated \((87.3\%)\) and soft-coated seeds \((79.7\%)\), while seeds supplied by informal seed dealers had the lowest germination both for soft-coated seed \((51.5\%)\) and for hard-coated seed \((72.9\%)\). Self-collected seeds had intermediate germination rates.

**Discussion**

*Types of tree seedling nursery, and mode and purpose of seedling production*

Government-owned nurseries dominate the seedling production landscape in the study area, with 62% of the nurseries and 73% of the produced seedlings. This agrees with results of Gebre \((2007)\) who already reported a higher proportion of government-owned nurseries compared to other categories in Ethiopia. Elsewhere, in most African and Asian countries, private commercial and individual farmer nurseries produced comparable to higher number of seedlings than government nurseries \((Nyoka et al. 2015)\). A number of advantages could be ascribed to the high number of government-operated nurseries, such as permanent locations with continued allocation of budget and steady clients (nurseries and seedling receiver) linkage through community tree planting campaigns. On the other hand, disadvantages of GO nurseries include relatively high running costs and less accessibility by farmers because of their location. While the massive seedling production and distribution by GO and NGO nurseries should continue, policy actions should also encourage seedling production by the community, the youth and the private sector as alternative means of income. Hence, other nursery categories – farmer operated, etc. – are essential to provide farming communities with adequate tree seedlings. Establishment of farmer nurseries, for example, could be facilitated by GOs and NGOs so that smallholder farmers play a pivotal role in tree germplasm supplies \((Böhringer et al. 2003)\). Shift of policy to support such nurseries will bring in income generation with increased tree seedling supply. This will free government resources to address tree germplasm quality control and supply of species that are difficult for community-based nurseries to handle \((Jaenicke 1999; Roshetko et al. 2010; Nyoka et al. 2015)\).

It is assumed that seedling production methods could have influence on seedling quality. Producing seedlings in containers confers higher chances of success of field establishment as such plants can better withstand damages during seedling transportation. Thus, seedlings produced by NGO-supported project nurseries can be expected to be of high quality since most of them are potted, while seedlings produced by farmer and government-owned nurseries can be expected to be of low quality as most of them are bare-rooted. Other studies in Africa \((Jaenicke 1999; Gebre 2007; Mbora et al. 2008; Sosola et al. 2011)\) have reported disadvantages associated with bare-root seedling production such as need for excellent soil, difficulties in disease and pest control, and intolerance to physical abuse and field planting stress even though the tree seedlings might be produced with maximum root development.

According to nursery operators, the high proportion of bare-rooted seedlings was caused by financial constraints thus calling for need to address seedling numbers against quality in nursery investment. However, both nurseries and the community prefer potted seedlings
as this can be translated to better seedling survival and growth out in the field. Hence, it would be wiser for higher bodies to set realistic seedling production targets that commensurate with the financial resources at their disposal than to continue with the current practice of setting very high targets with meagre resources.

With respect to the type of seedlings produced, the results indicate that most of the tree nurseries were giving relatively low consideration to food/fruit trees partly due to seed unavailability or lack of technical knowledge to produce the species. But the most important reason for not focusing on fruit trees is the notion that such high-quality grafted fruit trees are produced in specialized nurseries and not in ordinary tree nurseries. Traditionally and with government’s direction, most of the tree nurseries in the region are geared towards producing seedlings mainly for watershed management and fodder production, as also reported in Jonse et al. (2008). Other reports also indicate that tree seedlings are produced for the introduction of new agroforestry practices for the purpose of better fodder/forage production and soil fertility improvement (Tesfaye 2005; Khanal 2011).

The challenges the nurseries in the study area face are mainly on the supply side (i.e. lack of sufficient material and low seed quality), and this is partly in agreement with that reported for nurseries in Africa and Asia by Nyoka et al. (2015). The latter, however, identifies a problem in the demand side, lack of market, also as a very important challenge. This was not the case in our study area as most of the nurseries were undertaking free seedling distribution, and were not self-financed, rather government and NGOs financed them. However, such a free distribution by the other nurseries was a disincentive for the farmer nurseries in terms of diversification and boosting of seedling production. In general, free seedling distribution apparently undermines involvement of the private sector in the tree seedling business.

Tree seedlings, whether distributed freely or marketed, need to be properly planted, protected and managed, including watering for the first one to two years, for good survival and growth. Hence, a shift from quantity to quality seedling production and management, and a distribution system that adds accountability to all actors would be needed to improve the whole system.

**Seed procurement approaches and criteria followed to select mother trees**

Seeds supplied by formal seed dealers are well-tested seeds with important information on their tags, but they only represent a little more than 1% of the total amount of seeds received by nurseries. Seeds supplied by informal dealers and self-collected seeds are from low-quality and readily available sources, but they represent almost 99% of the total amount of seeds received by nurseries. Thus, a key challenge facing nurseries is the procurement of seeds of high quality in sufficient quantities. The problem can be partly related to location and distance of the seed suppliers to nurseries and their poor capacity to meet demands. Nursery operators also collected seeds from a few mother trees pointing to high probability of using seeds of narrow genetic diversity. Collection from readily available sources appears to confirm Nyoka et al. (2015) results, in which germplasm of most native tree species in Africa is collected from the most accessible sections of forests without consideration of quality of the trees. Nursery operators and seed suppliers collecting seed from only a few mother trees is also a common problem to supply quality seed in Indonesia and the Philippines resulting in possibly poor genetic quality (Koffa & Roshetko 1999; Carandang et al. 2006; Roshetko & Mulawarman 2008).
The fact that the lowest amount of seed was supplied by the formal sector (1% of the total) agrees with the findings by Walelign (2008) that indicated that the formal sector supplies from 10 to 15% of the total volumes of crop, fruit/apple and coffee germplasm supply in the Southern, Nations, Nationalities and Peoples Region of Ethiopia. Likewise, Muriuki (2005) reported that the formal sources contributed only to 16% of the seeds in three study sites in Kenya. In Vietnam, Thi Lua et al. (2015) found that only 10–15% of fruit tree germplasm came from the formal seed sector. Gregorio et al. (2005) reported that the majority (83.8%) of the individual nursery operators in Philippines had independently collected their own seed since almost all of them (86.4%) attended training courses in nursery management sponsored by both government agencies and NGOs.

High genetic diversity is maintained by collecting seed from at least 25–30 mother trees located at a minimum distance of 50–100 m from each other (Gregorio et al. 2005). The extent of low genetic considerations in collection of seeds by the major tree suppliers in Ethiopia (the informal sector) is more alarming than it is in Kenya, where Muriuki (2005) reported that over 30% of the seed dealers used genetic quality-related considerations when collecting seeds. The findings also differ from those of Gregorio et al. (2005), who reported that seed collectors in the Philippines collected almost all tree seeds from mature mother trees (36.4%), with good stem form (100%) and freedom from diseases (45.4%). The two studies (Gregorio et al. 2005; Muriuki 2005) attributed the higher number of respondents reporting genetic considerations to training offered to nursery operators and farmers in agroforestry and tree seed issues. The poor seed quality undermines the value of the resultant trees as only seed of the best quality will result in trees of the highest value in the field. However, respondents in this finding purchased cheap seed without consideration of its quality since the value attached to high quality is highly compromised by the purchase system where low-cost suppliers are favoured without quality assurance. In addition, the low value in monetary terms attached to many of the tree seedlings is acts as a disincentive towards producing seedlings of high vigour and genetic quality.

Nevertheless, genetic, physical and physiological qualities need to be considered when producing or procuring seeds (Gregorio et al. 2005; Mbora et al. 2009). Jaenicke (1999) advises nursery operators to order seeds from a supplier who provides good documentation on seed since the documentation can help to judge quality before purchase. Percentage viability of a given seed batch may however be reduced if the seeds are collected before they have properly matured, and the vigour of seedlings may be low if the seeds were not collected from strong and healthy plants.

Seedling productivity of seed obtained as evaluated by nursery operators

The variability in seedling productivity between the soft- and hard-coated seeds and between seeds coming from different categories of suppliers implies: (1) soft-coated seed are more vulnerable to viability loss; (2) seed purchased from informal seed dealers have lower germination rate, resulting in higher operating costs for nurseries; (3) poor seed quality of overall seed received by nurseries probably results in poor quality or higher loss of out planted seedlings. As a result, there are still substantial yield gaps between achievable and actual yields both in terms of yield per unit of nurseries and yield per unit volume of seed purchased. This difference in seed quality within seed procurement and types in this study partly concurred with that of Muriuki (2005), which indicated that the genetic quality in the
informal seed supply system was questionable but no marked differences were observed in seed germination between the two groups. Generally, the less attention given to the genetic quality of tree seeds under distribution in the study area is highly alarming, and it may as well show the bigger picture in Ethiopian tree seed system. It is a well-established fact that the seed genetic quality will have great influence on the quality of seedling and its trees as well as farmers’ vulnerability to the effects of climate change (Tesfaye 2005; Sultan 2009; FAO 2011; Jamnadass et al. 2013). This will be even more pronounced with the expected unusually wet or dry conditions in Ethiopia (Asenso-Okyere & Jemaneh 2012), and thus genetic considerations should be given so that future plantations will be stable and adapt to climate change. Otherwise, as a result of the production of poor quality seedlings, achievement of the CRGE might be less than otherwise possible.

**Conclusions and recommendations**

The number of nurseries owned by farmers (individual, group) and NGOs is much less than that of government-owned nurseries. Different seed procurement approaches and nursery practices showed significant effects on the performance of nurseries in terms of quantitative and qualitative tree seedling production. NGOs produce mainly containerized seedlings, thus better quality seedlings than other nursery types, which produce mainly bare-rooted seedlings.

The nurseries in this study were mainly procuring their seeds from informal seed dealers that supply cheap but low-quality seeds. This indicates that most nurseries do not give high consideration to seed quality, which determines seedling quality. It is highly probable that seeds coming from a few, poor-quality mother trees will give genetically poor-quality seedlings. Hence, there is urgent need to organize the seedling supply system in the study area in order to build the capacity of informal dealers to deliver better quality seeds and to organize both seed dealers and nursery operators towards better quality control of seed quality and seed pooling.

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