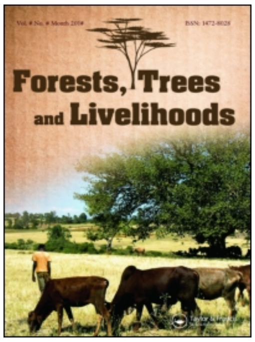

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Effect of pot size and growing media on seedling vigour of four indigenous tree species under semi-arid climatic conditions

Binyam Abera[a,b], Abayneh Derero[b], Samson Waktole[b] and Getaw Yilma[b]

[a]University of Lakehead, Toronto, Canada; [b]Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia

ABSTRACT
Appropriate nursery and tree planting technologies are vital for successful afforestation and reforestation. Seedlings of four important indigenous fodder and fruit tree species, *Acacia nilotica*, *Acacia tortilis*, *Dobera glabra* and *Ziziphus spina-christi*, were grown in three different levels of polybag pot size (8, 10 and 15 cm) and three different soil mixes (local topsoil, manure and sand). The experiment was implemented in a factorial randomized complete block design at the semi-arid Werer Center in the southern Afar, Ethiopia. Seedling height and root collar diameter were measured from second to seventh month after seed sowing. The results showed that seedlings raised in large pots had significantly greater height and root collar diameter, than those raised in the other two container types. On the contrary, there was no effect of the soil mix. We thus recommend the use of large polybag pots for seedling production in semi-arid areas as this will ensure greater success in tree establishment, though this may mean higher initial cost.

KEYWORDS
Afar; collar diameter; fodder tree; height; manure; nursery; soil mixture

1. Introduction

Successful tree growing in arid and semi-arid areas requires high seedling vigour, among other things. Nursery practices have effect on the vigour of seedlings and accordingly on the success of their transplantation in the field (Oliet et al. 2009; Del Campo et al. 2010). Nursery planting pots have been reported as one of the main factors affecting the successful development of seedlings (Dominguez-Lerena et al. 2006; Poorter et al. 2012), with large planting pots producing seedlings with a longer tap root during the nursery period, which favours the growth of a deep root system in the field (South et al. 2005; Pemán et al. 2006; Chirino et al. 2008).

Beside pot size, the soil mix can greatly influence both the vigour and the water status of the seedling through its effects on aeration, nutrition, and water holding capacity of the root plug (Bayley and Kietzka 1996; Marfà et al. 2002).

The influence of planting pot size and planting medium on seedling vigour for indigenous fodder and fruit species in pastoral and agro-pastoral areas of Afar has received almost no

CONTACT Abayneh Derero abaynehdd@yahoo.com

attention and to the best of our knowledge, no study has been reported. In this study we present the results of an experiment on the influence of planting pot size and growing substrate on the seedling vigour of four indigenous fodder and fruit tree species: *Acacia nilotica*, *Acacia tortilis*, *Dobera glabra*, and *Ziziphus spina-christi*.

2. Material and methods

2.1. Study site description

The study was conducted at the nursery of the Werer Agricultural Research Center (9°16′ North, 40°9′ East, 750 m a.s.l), located in the southern part of the Afar National Regional State, about 280 km east of Addis Ababa. The climate is typically semi-arid with an annual average rainfall of 590 mm. Its average monthly temperature is 26.7 °C with maximum temperature of 40.8 °C and minimum 26.7 °C (www.eiar.gov.et, accessed on 30 April 2015).

2.2. Experimental design

A full factorial (4 species × 3 pot size × 3 soil mix) randomized complete block design (RCBD) experiment was conducted and carried out with three replications and ten observations each. A participatory approach with the local pastoralist and agro-pastoralist (Derero et al. 2012) was used to select the four species (*A. nilotica*, *A. tortilis*, *D. glabra*, and *Z. spina-christi*). The 3 polybag pot sizes varied in diameter from small (8 cm), medium (10 cm) to large (15 cm). The height of all pot types was 15 cm. The 3 soil media were composed of a mix of local soil, manure and sand, in varying proportions: – soil mix 1 = 3:2:1 with 3 parts local soil, 2 parts manure and 1part sand; soil mix 2 = 3:2 with 3 parts local soil and 2 parts manure; and soil mix 3 = 2:1:1 (which represented the local practice) with 2 parts local soil, 1 part manure and 1 part sand. Local soil was collected from the top 20 cm of soil in a plantation neighbouring the experimental site. Manure was collected from the top 5 cm of a field where cattle regularly stayed overnight. Fine sand was collected from Awash River.

Seeds from 10 mature and healthy individuals per species (50–250 mature seeds per tree) were collected, bulked and sown on 23 May 2013 in a nursery seed bed watered twice a day early in the morning and late in the afternoon. Seeds germinated and grew under temporary shade made from wood support and grass top. Owing to germination and growth differences, seedlings of *A. nilotica*, *A. tortilis* and *Z. spina-christi* were transplanted on the 25th and *D. glabra* on the 45th day after sowing to pots with the different sizes and soil mixtures that were arranged in factorial RCBD design. The experimental site was also provided with temporary shade. Throughout the experiment, soil moisture was kept half way between field capacity and wilting point.

2.3. Data collection and analysis

Seedling height and root collar diameter were recorded every month from July 2013 to December 2013. Data were analysed with R Statistics (3.1.1). In case of significant difference between treatments, means were separated using the Tukey significant difference (Tukey-HSD) comparison test ($p < 0.05$).

3. Results

3.1. Species growth performances

Three species, namely *A. nilotica* and *Z. spina-christi*, raised in large pots filled with any of the three soil mixture types, and *A. tortilis* in large pots filled with soil mix 2 attained the required mean height in dry land regions (≥50 cm) fifth month after sowing. *D. glabra* was the shortest in any pot size and soil mix treatments, and attained a height below 20 cm in the same period (Figure 1). Seedlings of *A. nilotica* and *Z. spina-christi* raised in large pots were much thicker in root collar diameter than all other seedlings (Figure 2).

Seedlings of all tested species raised in large pots except *D. glabra* seedlings showed a faster and steadier height increment than when raised in other pot types (Figure 3). Similarly, seedlings of all tested species raised in large pots showed faster and steadier root collar diameter increment than seedlings raised in other pot types (Figure 4).

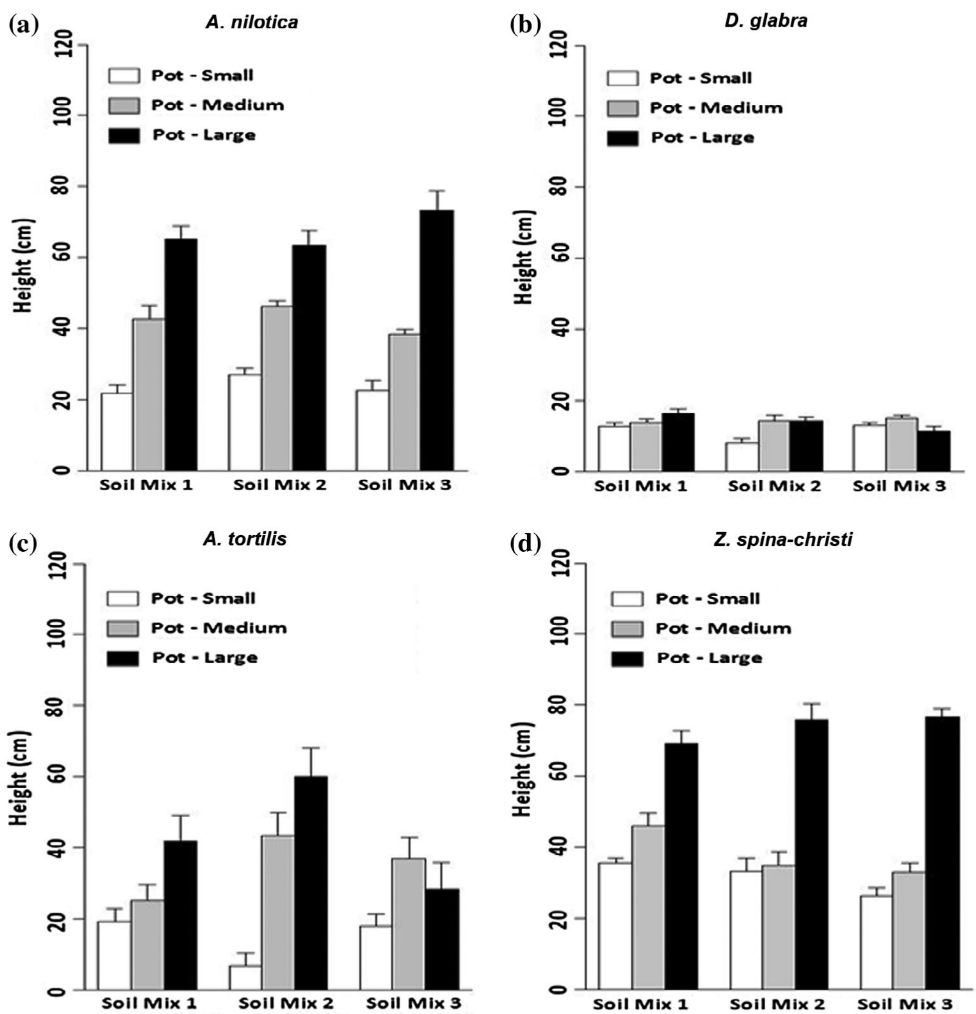

Figure 1. Seedling height under 3 pot size and 3 soil mixtures, about four month after transplanting in nursery pots. Mean and error-bars for each species, each with 30 siblings.

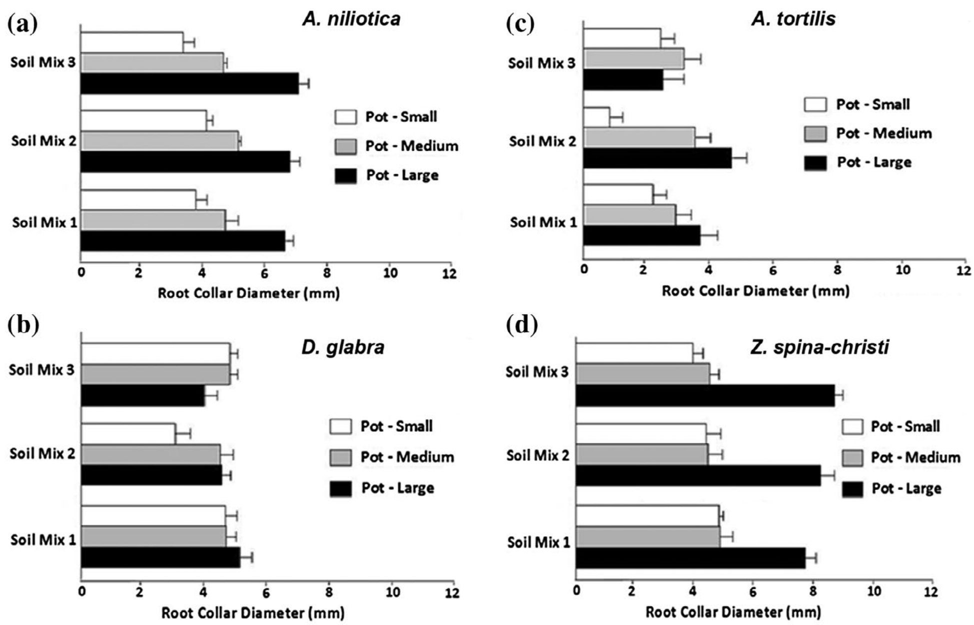

Figure 2. Root collar diameter under 3 pot size and 3 soil mixtures, about four month after transplanting in nursery pots. Mean and error-bars for each species, each with 30 siblings.

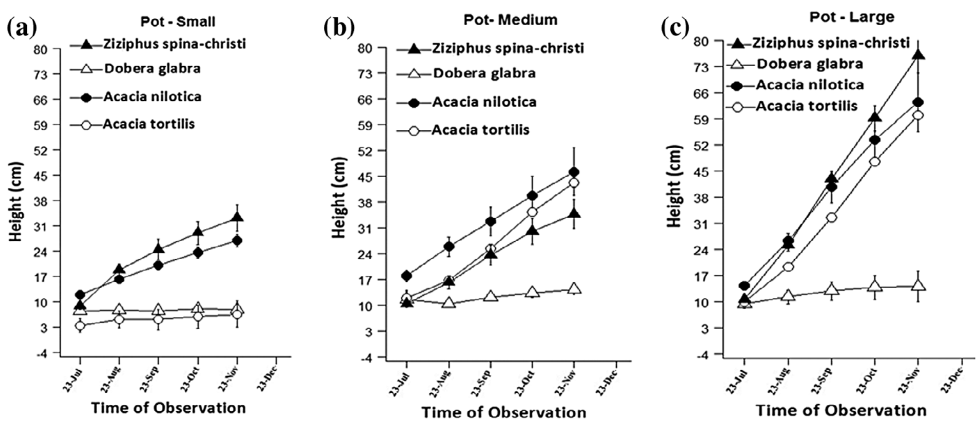

Figure 3. Seedling height increment under three pot size over five months. Means of height (cm) and error bars are presented for each species, each with 30 siblings. (a) Small pot size, (b) Medium pot size, and (c) Large pot size.

Separate within species analysis showed that seedlings raised in large pots had significantly larger height and root collar diameter than seedlings grown in other pot types, for all tested species except *D. glabra*. On the contrary, soil mixture type had no significant effect on the growth of any of the 4 tested species.

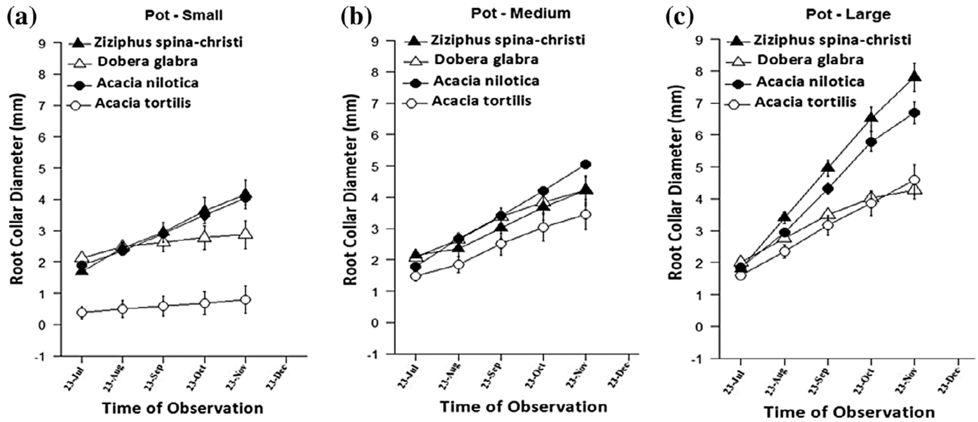

Figure 4. Seedling root collar diameter increment under three pot size over five months. Means of root collar diameter (mm) and error bars are presented for each species, each with 30 siblings. (a) Small pot size, (b) Medium pot size, and (c) Large pot size.

3.2. Species, pot size and soil mix interactions

The analysis of two-way interaction effects between species and pot size showed that *A. nilotica* and *Z. spina-christi* raised in large pots had significantly greater performances than *A. tortilis* and *D. glabra* in both height and root collar diameter (Table 1). Similarly, the analysis of two-way interaction effects between species and soil mix showed that *Z. spina-christi* had significantly larger height and root collar diameter than the other 3 species (Table 2).

4. Discussion

The positive effect of increasing planting pot size on seedling growth was reported for many plant species (e.g. Dominguez-Lerena et al. 2006; Dumroese et al. 2011).

Our results confirm that seedlings raised in large pots would be better developed and produced in a shorter time than seedlings raised in pots of smaller size. Better seedling performances in larger pots is due to the availability of more growing space, enabling the

Table 1. Two way-interaction effects between species and pot size on seedling height and root collar diameter after five months in the nursery.

Species	Pot size	Height	Root collar diameter
Ziziphus spina-christi	Small	31.64ef	4.15cde
	Medium	37.64cde	4.35cd
	Large	73.85a	7.78a
Acacia nilotica	Small	23.77f	3.66de
	Medium	42.42bcd	4.74bc
	Large	67.34a	6.73a
Dobera glabra	Small	11.21g	3.93cde
	Medium	13.93g	4.29cd
	Large	14.31g	4.40cd
Acacia tortilis	Small	14.47g	1.77f
	Medium	35.07de	3.14e
	Large	43.36bcd	3.56de

Note: For a given species, values with different letters in a column differed significantly ($p < 0.05$).

Table 2. Two way-interaction effects between species and soil mix on seedling height and root collar diameter after five months in the nursery.

Species	Soil mix	Height	Root collar diameter
Ziziphus spina-christi	S1	50.29a	5.51a
	S2	47.96a	5.39a
	S3	45.16abcd	5.41a
Acacia nilotica	S1	38.82cd	4.64abc
	S2	41.99abce	4.97ab
	S3	39.01bcd	4.52ab
Dobera glabra	S1	14.20f	4.55abc
	S2	12.16f	3.79cd
	S3	13.09f	4.28bc
Acacia tortilis	S1	28.64e	2.87de
	S2	36.69de	2.95de
	S3	27.56e	2.65e

Note: For a given species, values with different letters in a column differed significantly ($p < 0.05$).

early development of a long tap root to escape drought, a sine qua non condition for the success of transplantation in semi-arid or arid conditions.

Overall, the production of quality seedlings requires nutrient management, which was reported as a potential means to change morpho-functional traits of tree seedlings (Trubat et al. 2010). Some studies have reported significant growth differences under different soil mixes; for example, Fekadu et al. (2011) used different levels of manure, sand and local soil in a highland area but reported significant differences among the treatments. A study conducted in Costa Rica on three hardwood species also reported that species responded to substrate type (Wightman et al. 2001). However, this should not be generalized as our results show no significant differences in seedling growth between the tested soil mixes, which reinforces the need to quantify the physical and chemical properties of the substrates used to discuss such results (Wightman et al. 2001).

Our results showed that polybag size was the factor that had the greatest effect on seedling growth, suggesting that the effects of small or medium polybag size cannot be mediated by using appropriate planting soil mixtures. Proper decision on pot size selection can be rewarding as it may result in significant gains on seedling size and growth rate. We therefore recommend the use of large pots instead of small pots for seedling production in semi-arid and arid areas to ensure high seedling vigour and maximise the likelihood of success at transplantation.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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