Effects of substrate on germination and growth of *Moringa oleifera* Lam., *Acacia mellifera* (Vahl) Benth. and *Zizyphus mauritiana* Lam. seedlings

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Abstract

Despite the importance of forests and trees, Senegal is facing to the loss of forests and the decline of tree diversity and density. This study focuses on *Moringa oleifera* Lam., *Acacia mellifera* (Vahl) Benth. and *Zizyphus mauritiana* Lam. which constitute a significant source of food and economic value for the populations of Casamance. In addition to a germination test, a follow-up of seedlings on different substrates was carried out in the nursery, in order to determine the effect of substrates on some growth parameters (number of leaves, height, diameter and biomass). The substrates used were three potting mixtures of forest soil of *Faidherbia albida* (FSFA), *Elaeis guineensis* (FSEG) and *Anacardium occidentale* (FSAO) and sand with the following proportion: 1/3 sand + 2/3 forest soil). Based on species, the germination rate was higher for *A. mellifera* (84%) followed by *M. oleifera* (55%) and *Z. mauritiana* (50%). The germination rate was more important in FSFA and FSEG than in FSAO. For growth parameters, there was a significant effect ($P<0.05$) of substrate type on height, diameter, number of leaves and root biomass. In term of growth parameters, the seedling performed better in FSFA and FSEG than in FSAO. The species effect was also significant ($P<0.05$) with higher root biomass and diameter found in *M. oleifera* and height and number of leaves in *A. mellifera*. The most important total biomass was found in FSFA followed by FSEG. Comparing the fraction of biomass according to the part of the seedling, the stem and branch had the higher fraction of biomass for *A. mellifera* (43%) and *M. oleifera* (38%) and the leaves for *Z. mauritiana* (46%). However, the type of substrate can affect seedling development and growth parameters and the better results were recorded in FSFA and FSEG substrates.

Keywords

Moringa oleifera; *Acacia mellifera*; *Zizyphus mauritiana*; substrates; germination; growth; biomass; nursery

Contents

1 Introduction

Trees play an important role in the functioning of the savanna ecosystems (Sankaran et al. 2008) by maintaining soil chemical properties and nutrient cycling (Schlesinger et al. 1996; Reid et al. 1999) and providing direct or indirect human nutrition for developing countries particularly (Vinceti et al. 2008; Arnold et al. 2011). Most trees are also important sources of traditional medicines. The local populations highly value trees as a key resource that serves many functions and heavily exploit them (Ganaba and Guinko 1995). *Moringa oleifera, Acacia mellifera* and *Zizyphus mauritiana* are among the useful forest trees in Senegal. *M. oleifera* Lam.*, A. mellifera* and Z*. mauritiana* Lam. play an important role in harvesting activities and ecosystems services in Ziguinchor province *(*Ndiour 1996; Badiane 1996). *M. oleifera* originated from the foothills of the Himalayas in Northwestern India and is cultivated throughout the tropics (Nagao 2008). Moringa is very useful in the following areas; as alley cropping, animal forage, biogas, domestic cleaning agent, green manure, gum, medicine, ornamental plants, and water purification. Moringa leaves, seeds, and roots are also use in treating diseases like lung diseases, hypertension and skin infection (Fuglier 1999; WHO 2012). A. mellifera is a commonly occurring shrub on rangelands throughout the savannah in western, eastern and southern Africa. *A. mellifera* is also useful for its products used as food, fodder and timber and services such as good live fence. *Z. mauritiana* Lam. belongs to the family *Ramnaceae*. It is called jujube tree or Indian jujube (Morton 1987; Michel 2002). It is mainly used for fruit and medicine. The leaves of the plant are used in the treatment of diarrhea, wounds, abscesses, swelling and gonorrhea (Michel 2002). They are also used in the treatment of liver diseases, asthma and fever (Morton 1987).

Forests and trees face increasing and competing demands for land, wood, food, feed, energy and ecosystem services. Agriculture expansion is often at the expense of forests (Gibbs et al. 2010) and is considered the largest cause of deforestation, responsible for approximately 80% of forest loss (Kissinger et al. 2012). Soil properties, one of the important factors affecting distribution and growth of plants, play an important role in the ecology of vegetation (Ellenberg and Mueller-Dombois 1974; Sambou et al. 2017).

To prevent further loss of forests and trees, the government of Senegal has undertaken institutional reforms based on changed regulations and a new approach for managing trees and forests. This has included decentralization of power in 1996, a new environmental and forestry code and a change in policy towards participative approaches in natural resources management (Anon 2013; Anon 1998). Farmers are now in charge of tree resources on their own farms and territory, which may lead to the conservation of useful trees in the field (Sambou et al. 2017). Face to the loss of tree density and diversity, the government of Senegal has initiated many programs of reforestation and plantation. It is necessary to produce enough seedlings in quantity and quality.

Research results have however convincingly shown that one of the plant characteristics that affect growth rate and biomass production of trees is the quality of the planting stock (Fagbenro 2001). An important factor that has direct influence on the quality of the planting stock is the nature and component of the potting mixture used in the nursery for their production. Inorganic fertilizer is rarely used in Senegal to raise tree seedlings because of its economic cost and it can only supply the specific nutrients it contains to the soil. The productivity of permanent forest nurseries has become dependent upon the supply of organic materials such as compost and forest soil to improve the quality of the nursery potting mixture. In Senegal, the most used substrate in forest nursery is the forest soil of *Faidherbia albida*. But there are other organic materials that are more abundant in the environment and which can be processed to improve their effectiveness as organic soil conditioners or fertilizers.

In this study, our aim was to investigate the effect of different substrates of forest soil on the germination, the growth and productivity of *M. oleifera*, *A. mellifera* and *Z. mauritiana* seedlings when applied in mixture with sand.

2 Material and methods

2.1 Study area

The experiment was conducted at the Teaching and Research Farm of Department of Agroforestry Assane Seck University of Ziguinchor, Ziguinchor. The farm is geographically located at 12°32’ 57.2" latitude north and 16°16’ 37.3" longitude west. This farm is located in an area characterized by average rainfall between 1300 and 1500 mm per year. The relative humidity influenced by the harmattan is low in January, February and March (Figure 1).

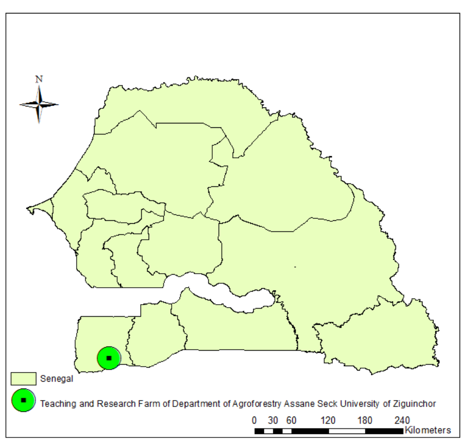

Figure 1. Location of Teaching and Research Farm of Department of Agroforestry Assane Seck University of Ziguinchor, Ziguinchor.

2.2 Vegetal material

Seeds of *M. oleifera, A. mellifera* and *Z. mauritiana* were subjected to three pre-germinating treatments before being sown. *A. mellifera* seeds were soaked in concentrated sulfuric acid for 30 minutes followed by soaking in water for 10 minutes (Roussel 1995). For *Z. mauritiana*, seeds were treated by soaking in concentrated sulfuric acid for just five minutes followed by soaking in warm water for five minutes (Roussel 1995). *M. oleifera* seeds were soaked for 24 hours in warm water (Roussel 1995).

The seeds of *M. oleifera* and *Z. mauritiana* used were collected in Lower Casamance (Oussouye and Ziguinchor) and *A. mellifera* come from National Forest Seed Program (PRONASEF). For *M. oleifera*, after fruit extraction and mixing with water to remove the maximum amount of pulp, the seeds were stored at room temperature (25 °C). A germination test was carried out for the purpose of evaluating germination. The seeds were sown in polyethylene bags of potting soil. In each polyethylene bag, three seeds were sown. Observations on germination were made for 28 days.

2.3 Substrate and potting mixture preparation

Forest soil of *Faidherbia albida* (FSFA), *Elaeis guineensis* (FSEG) and *Anacardium occidentale* (FSAO) were collected from remnant vegetation area of Assane Seck University of Ziguinchor. The potting mixture of forest soil has been made up of the following different proportion/ratio: 1/3 sand + 2/3 forest soil. Polyethylene bags of 24.5 cm x 15 cm were used for potting purpose.

2.4 Experimental design

Nursery experiment was carried in Complete Randomized Block Design with four blocks during three months. Three potting mixtures of forest soil of *Faidherbia albida* (FSFA), forest soil of *Elaeis guineensis* (FSEG) and forest soil of *Anacardium occidentale* (FSFAO) with sand were used. Three species which were *Acacia mellifera* (AM), *Moringa oleifera* (MO) and *Zizyphus mauritiana* (ZM) were used as vegetal materials. The combinaisons between species and potting mixture have been employed as treatments. Nine treatments which were FSFA-AM, FSEG-AM, FSAO-AM, FSFA-MO, FSEG-MO, FSAO-MO, FSFA-ZM, FSEG-ZM and FSAO-ZM were used. Each traitement was repeated randomly ten time in each block (Figure 2).

2.5 Data collection

Emergence of seedlings was recorded daily over a period of 28 days. Counts were made of the number of emerged seeds and the plumule emergence was considered to determine the germination rate. A seed is considered to have germinated when the cotyledons separate to allow the radicle to emerge (Diallo 2002).

The total germination rate, the germination rates per species and substrate were calculated.

Growth parameters like diameter, height and number of leaves were assessed. These parameters were determined at 10 days intervals starting from 10 days to 40 days.

After three months, the experiment was terminated by uprooting the whole plant in order to determine the dry weight of shoot and branch, leaves and root of the samples. Five polythene bags per treatment and species were randomly selected. 28 seedlings of *A. mellifera*, 15 of *M. oleifera* and 17 of *Z. mauritiana* were randomly taken and their diameter and height measured. The seedlings were divided into aboveground and belowground parts. Root systems were washed with tap water and dried with tissue. All seedling parts (root, stem, branch and leaves) were weighed fresh. After the fresh weight, the components were dried at 70°C for 72 hours. The dried samples were weighed separately. Total plant dry biomass (TDB) was determined as a sum of dry biomass of all components including root (R), stem and branch (SB) and leaves (L) dry biomass (DB). The relative water content (RWC) was determined according the following formula:

$$\frac{Mf - Md}{Mf} \times 100$$

Where *Mf* is the fresh mass of seedlings and *Md* is the fried mass of seedlings. The fraction of stem and branch dry biomass (SBDB), root dry biomass (RDB) and leaves dry biomass (LDB) were calculated.

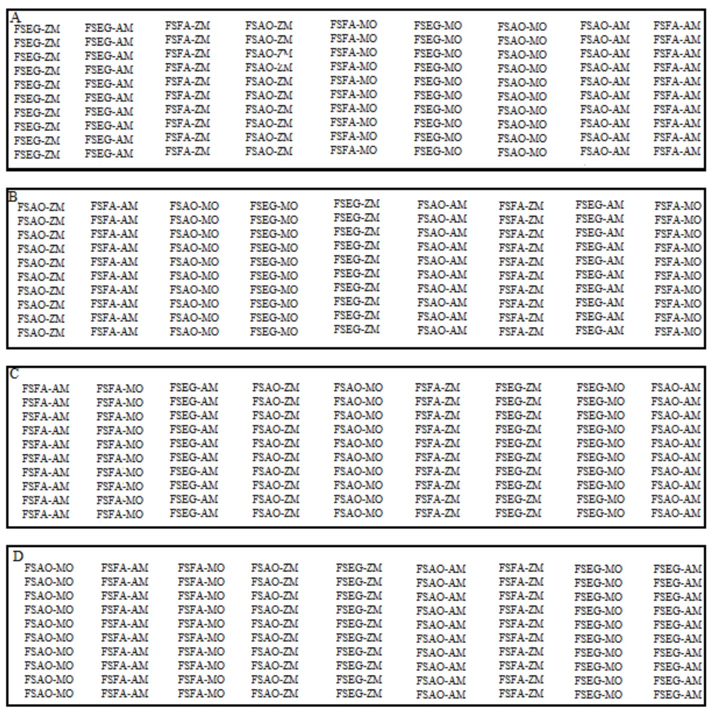

Figure 2. Experimental design, block 1 (A), block 2 (B), block 3 (C) and block 4 (D).

2.6 Statistical analysis

Data collected were subjected to two-way analysis of variance (ANOVA) performed with R 3.2.4 (Team 2015). When effects were significant, Tukey's test was used for multiple mean comparisons to detect the significant differences between the substrates and species. Statistical significance was fixed at 0.05. The allometric relationships between dry biomass components and diameter were analyzed using one-way ANOVA.

3 Results and Discussion

3.1 Results

3.1.1 Germination rate

The total germination rate was 62.31%. The substrate effect on germination rate was not significant (P=0.93). Comparing the germination rate by substrate, the higher germination were registered in FSEG followed by FSFA and FSAO, while the species affected significantly (P<0.05) the germination rate. Based on species, the germination rate was higher for *A. mellifera* followed by *M. oleifera* and *Z. mauritiana* (Table 1).

Table 1. Effects of substrates and species on germination rate.

Parameter		Germination rate
Substrate	FSFA	60.83 ± 15.83^{a}
	FSEG	65.83 ± 18.93^{a}
	FSAO	60.27 ± 23.96^{a}
Species	AM	83.89 ± 4.88^{a}
	ZM	47.78 ± 9.59^{b}
	MO	55.27 ± 2.40^{b}

3.1.2 Growth parameters

There were significant effects of substrate on growth parameters (P<0.05). The growth parameters performed better in FSFA than in FSEG and FSAO. Therefore, the lower performance was registered in FSAO (Figure 2). The diameter and height growth were significantly faster in FSFA (0.40 ± 0.16 cm and 32.88 ± 12.71 cm respectively) and in FSEG (0.39 ± 0.15 cm and 29.67 ± 11.56 cm) than in FSAO substrate (0.35 ± 0.16 cm and 27.04 ± 13.60 cm) (Figure 2a and b). The higher of number of leaves was recorded in FSFA substrate (64.04 ± 57.65) followed by FSEG (47.98 ± 44.18) and FSAO (44.30 ± 41.11) (Fig 3c). There was a large variation within substrates characterized by the large error bars (SD). Species performed differently within substrates. The species influenced significantly the growth parameters (P<0.05). *M. oleifera* grow faster in diameter than *A. mellifera* and *Z. mauritiana*. For the height and the number of leaves, the better performance was registered in *A. mellifera* followed by *Z. mauritiana.* There was a large variation within species for growth parameters characterized the large standard deviations. The species performed differently across the substrate, especially *A. mellifera* and *Z. mauritiana*. The growth parameters of *A. mellifera* and *Z. mauritiana* performed significantly better in FSFA substrate compared to FSEG and FSAO substrates. *M. oleifera* growth was not influenced significantly (P>0.05) by the substrates (Table 2, 3 and 4).

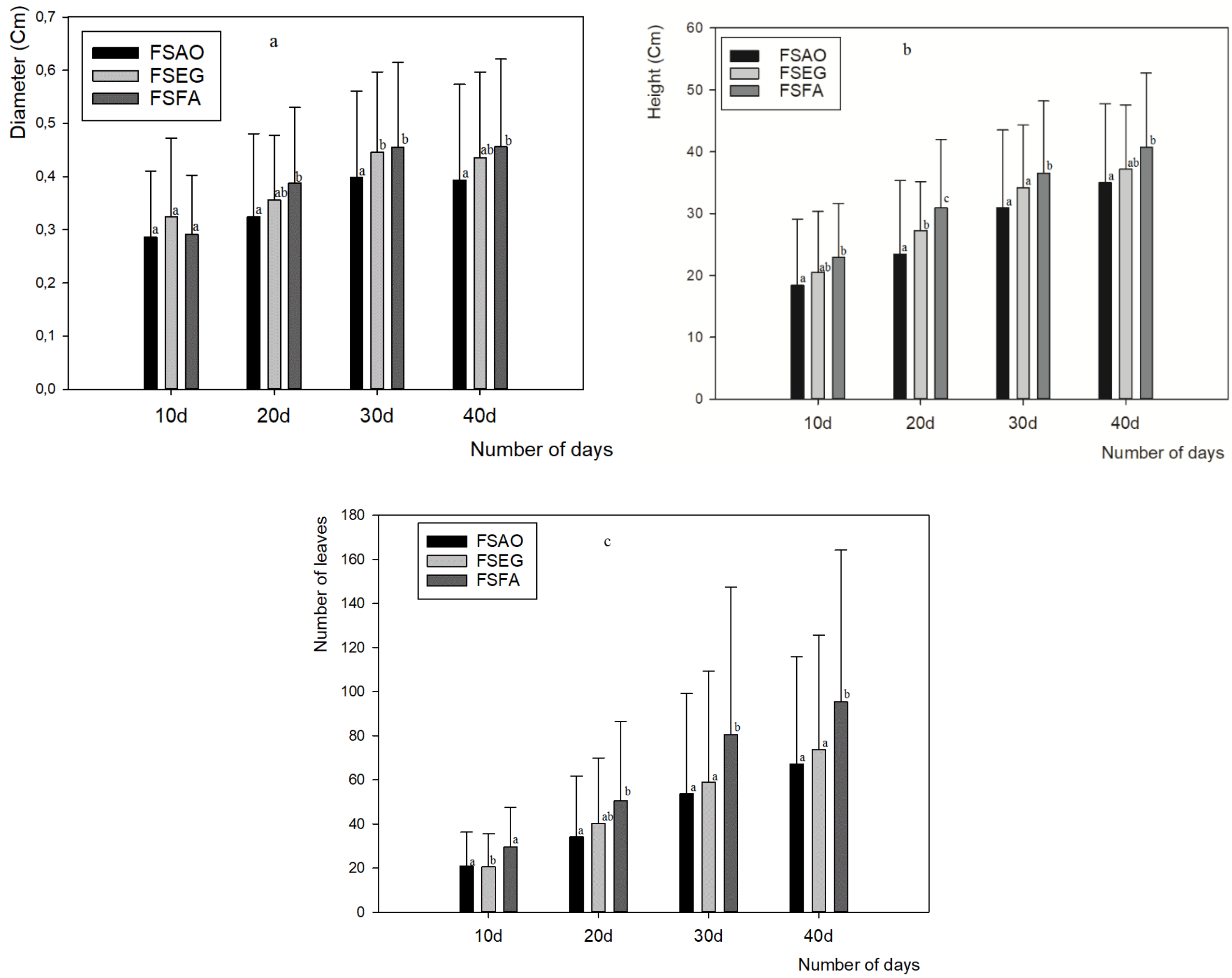

Figure 3. Effects of substrates on growth parameters: diameter (a), Height (b) and number of leaves (c). Histograms are means and error Bars are standard deviations (SD) of growth parameters of seedlings (diameter, height and number of leaves).

Table 2. Effects of species on diameter growth within substrates. Mean (standard deviations, SD).

Substrate	Species	Diameter (cm)			
		10d	20d	30d	40d
FSAO	AM	0.31±0.08^a	0.34±0.09^a	0.42±0.11^a	0.41±012^a
	ZM	0.23±0.04^b	0.24±0.06^b	0.32±0.09^b	0.32±0.10^b
	MO	0.58±0.29^c	0.63±0.35^c	0.81±0.35^c	0.84±0.39^c
FSEG	AM	0.29±0.08^a	0.33±0.08^a	0.42±0.09^a	0.42±0.09^a
	ZM	0.26±0.06^a	0.32±0.08^a	0.38±0.09^b	0.37±0.07^a
	MO	0.56±0.17^b	0.57±0.14^b	0.71±0.23^c	0.73±0.23^b
FSFA	AM	0.31±(0.08)^a	0.39±0.10^a	0.46±0.11^a	0.45±0.11^a
	ZM	0.24±0.05^b	0.34±0.11^a	0.41±0.11^a	0.40±0.10^a
	MO	0.56±0.24^c	0.59±0.24^b	0.66±0.30^b	0.69±0.32^b

Table 3. Effects of species on height growth within substrates.

Substrate	Species	Height (cm)			
		10d	20d	30d	40d
FSAO	AM	25.37± 9.69^{a}	28.10± 9.37^{a}	40.66± 10.63^{a}	42.97± 10.21^{a}
	ZM	10.58± 8.19^{b}	15.53± 8.98^{b}	25.28± 10.02^{b}	26.81± 9.69^{b}
	MO	25.52± 9.35^{a}	31.77± 18.65^{b}	33.23± 11.71^{ab}	36.74± 13.01^{ab}
FSEG	AM	23.4± 7.05^{a}	28.54± 7.82^{a}	39.06±11.37^{a}	40.74± 11.35^{a}
	ZM	14.57± 6.61^{b}	25.59± 7.95^{a}	32.99± 7.97^{b}	33.84± 8.06^{b}
	MO	27.42± 13.60^{a}	28.65±7.11^{a}	33.74± 10.50^{ab}	36.84± 10.22^{ab}
FSFA	AM	27.64± 5.81^{a}	32.92± 9.22^{a}	42.51± 10.05^{a}	44.53± 10.28^{a}
	ZM	18.95± 9.20^{b}	28.70± 10.44^{a}	36.62± 11.01^{ab}	38.57± 11.00^{ab}
	MO	16.9± 1.12^{b}	34.29± 18.09^{a}	31.21± 16.87^{b}	34.16± 17.48^{b}

Table 4. Effects of species on number of leaves within substrates.

Substrate	Species	Number of Leaves			
		10d	20d	30d	40d
FSAO	AM	28.18± 14.89^{a}	45.68± 29.20^{a}	78.79± 48.00^{a}	88.30± 47.67^{a}
	ZM	15.48± 13.60^{b}	24.40± 19.34^{b}	48.65± 41.06^{b}	53.43± 41.74^{b}
	MO	5.6± 1.14^{b}	7.17± 1.60^{b}	7.90± 2.23^{c}	8,40± 2.30^{b}
FSEG	AM	26.53± 13.56^{a}	41.83± 23.02^{a}	77.68± 48.03^{a}	87.68± 47.71^{a}
	ZM	21.38± 15.19^{a}	47.90± 33.55^{a}	72.71± 50.99^{a}	79.33± 50.00^{a}
	MO	5.72± 1.56^{b}	7.00± 1.61^{b}	7.58± 1.95^{b}	8.08± 1.93^{b}
FSFA	AM	35.78± 16.91^{a}	57.05± 32.17^{a}	105.70± 64.85^{a}	116.03± 63.81^{a}
	ZM	26.13± 17.01^{b}	53.70± 6.85^{a}	90.08± 66.32^{a}	96.43±66.14^{a}
	MO	7.2± 0.45^{c}	7.30± 1.77^{b}	8.10± 1.86^{b}	8.60± 1.84^{b}

3.1.3 Seedlings biomass

The substrate and species effects were only significant for root dry biomass (Table 5). Total biomass ranged from 1.24 g to 6.34 g seedling^{-1} across substrates and species. The high productivity in term of biomass for different components was registered in FSFA substrate followed by FSEG.

Table 5. Effects of substrates and species on dry biomass components.

Substrate	Species	Dry biomass (g)			
		Plant	Root	Stem and branch	Leaves
FSAO	AM	1.24±0.7^{a}	0.29±0.18^{a}	0.55±0.34^{a}	0.48±0.33^{a}
	ZM	2.82±2.67^{a}	0.56±0.37^{ab}	1.03±1.26^{a}	1.25±1.08^{a}
	MO	2.70±2.36^{a}	0.82± 0.53^{b}	0.88±0.86^{a}	0.92± 1.08^{a}
	Grand mean	**1.93± 1.81^{a}**	**0.47± 0.38^{a}**	**0.74± 0.74^{a}**	**0.75± 0.78^{a}**
FSEG	AM	2.24±1.89^{a}	0.38±0.14^{a}	0.89±0.86^{a}	0.86±0.94^{a}
	ZM	2.66±1.67^{a}	0.73± 0.46^{a}	0.86± 0.56^{a}	1.08± 0.66^{a}
	MO	3.84±4.80^{a}	0.76± 0.70^{a}	1.66± 1.91^{a}	1.46± 2.24^{a}
	Grand mean	**2.77± 2.77^{a}**	**0.57± 0.45^{a}**	**1.08± 1.16^{a}**	**1.08± 1.29^{a}**
FSFA	AM	4.39±4.29^{a}	0.87±0.72^{ab}	2.02±1.98^{a}	1.52±1.69^{a}
	ZM	1.58±1.09^{a}	0.41±0.28^{a}	0.46± 0.38^{a}	0.73± 0.44^{a}
	MO	6.34±4.53^{a}	1.74± 0.81^{b}	2.48± 1.95±^{a}	2.10± 1.83^{a}
	Grand mean	**3.87± 3.86^{a}**	**0.93± 0.80^{b}**	**1.57± 1.73^{a}**	**1.38± 1.44^{a}**

Table 6. Effect of substrate and species on relative water content of components.

Substrate	Species	Relative water content			
		Plant	Root	Stem and branch	Leaves
FSAO	AM	0.69± 0.04^{a}	0.72± 0.05^{a}	0.61±0.05^{a}	0.69± 0.13^{a}
	MO	0.88±0.03^{b}	0.89± 0.03^{b}	0.85± 0.09^{b}	0.90± 0.06^{ab}
	ZM	0.65± 0.19^{a}	0.71± 0.12^{a}	0.62± 0.15^{a}	0.60± 0.28^{b}
	Grand mean	**0.72± 0.12^{a}**	**0.76± 0.10^{a}**	**0.67± 0.13^{a}**	**0.72±0.19^{a}**
FSEG	AM	0.56± 0.12^{a}	0.59± 0.16^{a}	0.53± 0.20^{a}	0.61± 0.15^{a}
	MO	0.86± 0.02^{b}	0.88± 0.02^{b}	0.85±0.01^{b}	0.87± 0.05^{b}
	ZM	0.75± 0.05^{b}	0.75± 0.08^{ab}	0.68± 0.09^{ab}	0.77±0.02^{b}
	Grand mean	**0.69± 0.16^{a}**	**0.71± 0.17^{a}**	**0.65± 0.20^{a}**	**0.72± 0.15^{a}**
FSFA	AM	0.65± 0.06^{a}	0.66± 0.11^{ab}	0.57± 0.04^{a}	0.69± 0.07^{a}
	MO	0.86± 0.01^{b}	0.87± 0.04^{a}	0.86±0.03^{b}	0.85± 0.05^{b}
	ZM	0.65± 0.14^{a}	0.55± 0.29^{b}	0.61± 0.22^{a}	0.63± 0.12^{a}
	Grand mean	**0.70± 0.13^{a}**	**0.68± 0.22^{a}**	**0.66± 0.18^{a}**	**0.71± 0.12^{a}**

On average, Moringa *oleifera* had the greatest total dry biomass. *Acacia mellifera* and *Zizyphus mauritiana* had the lowest total dry biomass. Comparing the fraction of dry biomass components, the majority of dry biomass was allocated into stem and branch (1.03 ± 1.22 g and 1.67 ± 1.67 g respectively for *Acacia mellifera* and *Moringa oleifera*) and leaves (0.98 ± 0.72 g) for *Zizyphus mauritiana* (Table 5).

The comparison of the relative water content (Table 6) on the three substrates with Tukey's test showed no significant differences ($P>0.05$). The higher relative water content for plant was found in FSAO substrate followed by FSFA and FSEG. The most important relative water content was registered in root and leaves. Only the species had a significant effect on relative water content ($P<0.05$). The relative water content was significantly higher in *M. oleifera* compared to *Z. mauritiana* and *A. mellifera* (Table 6).

Allometric analysis showed a good relationship between dry biomass components and diameter characterized by negative intercepts, positive slopes and coefficient of determination (R^2) varying between 0.25 and 0.97 (Table 7). The analysis of bivariate relationships between dry biomass components and diameter revealed significant differences among species in coefficients of determination of allometric relationships. The coefficient of determination of *Moringa oleifera* (R^2=0.89 ± 0.10) was significantly greater than *Acacia mellifera* (R^2 = 0.75 ± 0.08) and *Zizyphus mauritiana* (R^2 = 0.61 ± 0.19) (Table 8).

Table 7. Relationships between dry biomass components and diameter (D).

Substrate	Species	variable1	variable 2	Intercept	Slope	R^2
FSAO	AM	Plant	D	-1.1	8.35	0.61
		Leaves	D	-0.78	4.46	0.78
		Stem and branch	D	-0.69	4.41	0.73
		Root	D	-0.34	2.22	0.68
	ZM	Plant	D	-3.57	18.82	0.4
		Leaves	D	-1.59	8.34	0.48
		Stem and branch	D	-1.38	7.07	0.25
		Root	D	-0.57	3.32	0.63
	MO	Plant	D	-2.59	9.98	0.97
		Leaves	D	-1.5	4.57	0.97
		Stem and branch	D	-0.95	3.45	0.89
		Root	D	-0.23	1.98	0.76
FSEG	AM	Plant	D	-5.54	22.17	0.8
		Leaves	D	-3.02	11.07	0.8
		Stem and branch	D	-2.3	9.07	0.64
		Root	D	-0.18	1.6	0.78
	ZM	Plant	D	-1.86	7.41	0.6
		Leaves	D	-0.79	3.05	0.66
		Stem and branch	D	-0.71	2.57	0.64
		Root	D	-0.36	1.79	0.45
	MO	Plant	D	-9.06	17.44	0.96
		Leaves	D	-4.57	8.14	0.96
		Stem and branch	D	-3.43	6.88	0.95
		Root	D	-1.11	2.53	0.95
FSFA	AM	Plant	D	-5.62	25.29	0.84
		Leaves	D	-2.24	9.54	0.79
		Stem and branch	D	-2.64	11.78	0.85
		Root	D	-0.75	4.03	0.73
	ZM	Plant	D	-1.45	8.16	0.83
		Leaves	D	-0.49	3.29	0.83
		Stem and branch	D	-0.6	2.86	0.86
		Root	D	-0.33	1.97	0.74
	MO	Plant	D	-4.69	14.48	0.88
		Leaves	D	-2.23	5.69	0.83
		Stem and branch	D	-2.28	6.25	0.88
		Root	D	0.03	2.24	0.65

Table 8. Allometric analysis testing differences among the substrates and species.

Parameters	Substrate			Species		
	FSAO	FSEG	FSFA	AM	MO	ZM
Intercept	1.27 ± 0.97^a	2.74 ± 2.62^a	1.94 ± 1.76^a	2.10 ± 1.88^a	2.72 ± 2.51^a	1.14 ± 0.93^a
Slope	6.42 ± 4.68^a	7.81 ± 6.50^a	7.96 ± 6.74^a	9.50 ± 7.48^a	6.97 ± 4.90^a	5.72 ± 4.82^a
R^2	0.68 ± 0.22^a	0.77 ± 0.17^a	0.81 ± 0.07^a	0.75 ± 0.08^a	0.89 ± 0.10^b	0.61 ± 0.19^c

3.2 Discussion

3.2.1 Germination rate

To understand the influence of substrate and species on germination, we investigated the germination rate of *A. mellifera*, *M. oleifera* and *Z. mauritiana*. The substrate effect on germination rate was not significant in our study. Seedling survival rate was significantly affected by difference in potting mixture for both tree species (Mulugeta 2014).The species influenced significantly the germination rate. There was a significant differences between species in term of germination rate. Our results showed low germination rate compared to previous findings for *M. oleifera* and *Z. mauritiana* germination. The germination rate of *M. oleifera* was relatively low compared to results founded by other researchers. Regarding the direct seeding, the *M. oleifera* seeds collect from dry pods and should be planted two centimeter (cm) deep that germinate about one to two weeks (Jahn et al. 1986), stated that the rate of germination is usually between 60%-90% for fresh seeds. *M. oleifera* seeds soaked for 12 and 72 hours provided the best germination rate (90%) (Pamo et al. 2005). The emergence percentage of *Z. mauritiana* was high (98.4%) (Ramírez et al. 2012). But for *A. mellifera*, an important germination rate was recorded. Periodic water stress induced higher total germination capacity (83%) for *A. mellifera* (Abdalkreem and Siam 2017).

3.2.2 Growth parameters

We hypothesized that substrate and species would influence the growth parameters. Our hypothesis was totally supported because we found significant influence of substrate and species on growth parameters. The result is in line with Abebe (2000), who also reported that different soil mixtures affected the growth of shoot and root differently. The growth parameters performed better in FSFA than in FSEG and FSAO. This is due to the difference in nutrient composition between substrates. The shoot and root growth of the seedling were minimum in pure local top soil or control, which could be due to absence of compost/organic matter and forest soil in soil substrate (Mulugeta 2014). The forest soil of *F. albida* is rich in sol fertilizers (Giffard 1964). The forest soil of *F. albida* has an important content of organic matter, N, P, K and exchangeable Na, Ca and Mg (Kamara and Haque 1992). By comparing the properties of soil under cashew with that under an adjoining logged rain forest, the levels of organic carbon, nitrogen, exchangeable calcium and magnesium, and available phosphorus were similar under logged forest and cashew, suggesting that organic matter and nutrient cycles in a cashew plantation are similar to those in a logged rain forest (Aweto and Ishola1994). The fertilizing power of *E. guineensis* has been emphasized in the work of Camara et al. (2017) and Akouehou et al. (2013).

The species influenced significantly the growth parameters. Growth rate depended on species. *M. oleifera* and *A. mellifera* were the faster growing species than *Z. mauritiana*. *M. oleifera* is a fast growing tree and able to tolerate wide range of environmental conditions, as it is drought tolerant and requires rainfall ranges between 250 to 1500 mm (Price 2000). It tolerates both sandy soils, heavier clay soils and water limited conditions and may survive in less fertile soils (Anwar et al. 2007). M. oleifera grows either by direct seeding or planting stem cuttings (Palada 1996).

3.2.3 Seedlings biomass

The results of this study showed that only the dry biomass of root was significantly influenced by the substrate and species. There was no significant difference between root, stem and branch, leaves and total plant dry biomass. But for A. mellifera, there was significant difference between dry biomass components. Similar results have been reported by Sherzad et al (2016) by testing the effect of shade on biomass allocation of *Neobalanocarpus heimii.*

The aim of allometric relationships was to establish allometric equations to avoid the destructive method of biomass evaluation. In this study, the linear relationship between dry biomass components and diameter was assessed. This linear relationship was characterized by a positive correlation (positive slopes) between dry biomass components and diameter. Similar results were also reported by (Lazim et al. 2007), they stated that there was strong positive correlation dry biomass components and various tree growth parameters (height, crown area and diameter at the base of stem) in both *Acacia tortilis* and *A. mellifera*. To better understand the allometric relationships between dry biomass components and diameter among substrates and species, we tested the coefficients (intercept, slope and coefficient of determination) of the allometric analyses. We hypothesized that substrates and species would differ in allometric relationships between dry biomass components and diameter. We found significant variation among the species in coefficient of determination (R^2). Substrates and species had not influenced significantly the intercepts and slopes of allometric relationships. A significant variation among families in both intercepts and slopes of allometric relationships at the seedling stage of *Picea abies* was found by Chmura et al. (2017).

4 Conclusion

The FSEA and FSAO substrates gave the best results for the germination of *M. oleifera*, *A. mellifera* and *Z. mauritiana*. The growth parameters of nursery species varied depending on the substrate. Thus, the better performance of growth parameters was recorded in FSFA and FSEG. But FSAO substrate registered non-negligible results in term of growth parameters. The knowledge of the better substrates which are FSFA and FSEG and the mastery of the technical process of nursery forest species are an important step to facilitate reforestation and plantation of *M. oleifera*, *Z. mauritiana* and *A. mellifera* and secure the socio-economic and environmental role played by these species for rural populations. This could help to reverse the trend of declining plant genetic resources through this process of domestication.

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