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The effects of seed pretreatment on seed germination and biochar soil mixture on early survival of seedlings of *Faidherbia albida (Del) Chev* in nursery

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Abstract: Appropriate pretreatment of seed and soil mixture of nursery are required for proper seed germination and seedlings growth, respectively. *Faidherbia albida* (Del) Chev (syn. *Acacia albida* [Del.]) is a useful tree species that improve soil fertility, and supply dry season livestock fodder in some climatic zones of Africa. However, it is difficult to grow *F. albida* in clay soils and methods to improve the cultivation conditions are highly required. Although biochar can be a potential ingredient of nursery soil mixture in deforested areas, information is lacking about its effect in clay soil nursery sites. Seeds of *F. albida* are also difficult to germinate in a short period of time. Accordingly, this study was conducted to determine the effects of nicking, and warm and cold water stratification seed pretreatments on improving the seeds germination. Then different proportional ratios of bio-chars of saw dust, chat (*Catha edulis* Forsk) leaves and coffee (*Coffea arabica* L.) husks pyrolysed at 300 and 350°C temperature were mixed with local soil, and compost to grow transplanted seedlings in the first year of eight months and then continued to second year totally 20 months old. Among the presowing seed treatment, stratification resulted in greatest number of germination of the seeds, about 76%. The effect of the soil mixtures on the root collar diameter (RCD) growth was greater than the corresponding stem height growth. The greatest RCD and height growth was obtained from local soil, about 0.84cm, and 28cm, respectively. The minimum growth of RCD was obtained in soil mixtures of local soil, compost and biochar of sawdust 350°C. However, 25% biochar of saw dust 300°C showed maximum RCD growth in eight months. In the first year, although, the soil mixture that contained only local soil was the best in increasing the growth of RCD and height of seedlings, it was the least in the number of seedlings survived. In 20months, the highest survival about 94%, root collar diameter of 0.88cm and height of 30.85cm was obtained from the mixture of local soil and biochar of sawdust 300°C in the ratio of 03:01, while the least survival and growth was obtained from unmixed local soil. Soil mixtures that contained biochar in all cases improved the survival of seedlings. Therefore, seedling growing in clay loam soils should include biochar pyrolysed at appropriate temperature for better survival of seedlings of *F. albida*.

Keywords: bio-char, height, root collar diameter, seedlings, soil mixture, survival

Introduction

Faidherbia albida ((Delile) A. Chev) belongs to the family Fabaceae. Its common names are Apple-ring acacia or winter thorn. The apple-ring acacia was previously called *Acacia albida* Del., but currently named as *Faidherbia albida* (Delile) A. Chev.). It is a deciduous legume tree, up to 30 m height and has deep taproot, down to 40 m (Orwa et al., 2009). *F. albida* is native to arid or semi-arid areas of Africa. It is widely spread in Africa, found in the Middle-East and in South-East Asia, India, Pakistan, Cyprus, Cape Verde and Peru (Orwa et al., 2009). The tree grows in sandy areas with 250-1800 mm annual rainfall and long dry seasons, with 6- 42°C temperatures (Ecoport, 2009).

F. albida is nitrogen fixing leguminous tree species and its nutrient rich leave shed add nutrients like nitrogen, potassium, and carbon to soil (Umar *et al*., 2013). It is a fertilizer tree widely used in Semi-Arid Ethiopia (Azene, 2007) (Figure 1).

F. albida is one of the best agroforestry tree species because of its natural reverse phenology of shedding leaves in rainy season where under growing crops are growing, and growing leaves and ripening pods in dry season. The phenological characteristics of the tree species made it valuable in periods of scarcity of fodder (livestock feed supplementing) and famine food (edible seed). The ability to grow as a shade tree in hot weather and the ability to fix nitrogen made *F. albida* valuable for maintaining soil fertility (Ecoport, 2009). The tree allows satisfactory production of crops under a full stand (Kessler, 1990; Roupsard *et al*., 1999). The tree takes 15 to 30 years of growth to obtain the full benefit of new planting.

Figure 1: Scattered Faidherbia albida trees in farmlands of Semi-Arid Ethiopia

Although *F. albida* tolerates occasional water logging, it was difficult to grow in clay vertisols. Previous observations in Southern Ethiopia in Enemorina Ener district revealed that growing seedlings of *F. albida* was difficult because of poor seed germination, and poor aeration of rooting soil media. The difficulty in growing *F. albida* in clay soils requires methods to improve the cultivation practices.

Quality, vigorously germinated seedlings, determine the survival and growth of seedlings and future trees. Appropriate pretreatment or presowing seed treatment and soil mixture are management factors determining the growth of seedlings in nursery (Corbasson *et al*., 1986).

The strong seed coat of *F. albida* shows the presence of seed dormancy. The seeds are covered by waterproof cuticle which ensures their preservation for several years (Corbasson *et al*., 1986). The seed dormancy can artificially be removed by nicking or warm -cold water stratification.

Nicking large number of seeds is time consuming, tedious and could damage the internal part of endosperm (Evans and Blazich, 1999; Moser, 2006; Azene, 2007).

Tree seed nursery is an area where young trees are grown for future planting out in the field. The nursery has to have appropriate soil mixture with sufficient nutrient, and water. The appropriate soil mixtures are well decomposed forest soil; manure; sand and local soil (Simons, 1999). It is known that forest soil supplies optimal microbial composition and organic nutrient for the growing seedlings, manure supplies nutrient, sand supplies air space in the root, and local soil has the appropriate space for water holding. Soil mixtures are prepared to replace natural forest soils which provide the seedlings with good drainage, good nutrient content and mechanical support by holding the roots together. However, there are nursery sites that face shortage of forest soil because of the deforestation and replacement of forests by other landuses. Therefore, appropriate seedlings growth in the nursery requires a replacement of the short running forest soil and reduced supply of sand in clay soils.

F. albida poorly grows in clay soil where air supply is not sufficient. Biochar has a characteristic of nutrient retention and aeration. Biochar is a fine-grained and porous charcoal which is distinguished from other charcoals in its high surface area per unit of volume and low amounts of residual resins (Lehmann, 2007). Biochar has been used as soil amendment in different parts of the world. Biochar adsorb nutrients and water and also provide a habitat for beneficial microorganisms when compared to other soil amendments (Warnock *et al*., 2007). The quality of biochar is determined by temperature level used for pyrolysis and type of feedstock. The major feed stocks for biochar production are toxic free waste biomass, including forestry, or agriculture crop residues and urban food and paper wastes. Biochar catalyzes the plant uptake of nutrients and water (Hunt *et al*., 2010). When biochar is buried in soils, it takes carbon out of the atmosphere and traps it underground for hundreds of even thousands of years (David, 2014).

Biochar is incorporated in to soil by spreading in to the soil surface, mixing with compost or mulch, or pouring as liquid slurry. The soil type and type of crop affects the application rate for bio-char. Previous studies showed that biochar applications of 5 to 20 % by volume of soil have positive and noticeable results (Hunt *et al*., 2010).

The effect of biochar in the soil depends on the soil type, presence of other ingredients and the type of plant. Newly formed fresh biochar applied in to soil can retard plant growth the first year. The benefit of biochar to the soil is detected when biochar undergo a few changes in the soil before it can serve as a rooting media. The best way to prepare biochar for soil amendment is to mix with or blend with fertilizer, rock dust, or compost (David, 2014). The mixtures of biochar and compost have synergistic benefits including increasing microbial activity, and reducing nutrient losses (Dias *et al*., 2010). The combination of biochar with compost improves the growth of plants as biochar adsorbs gases (ammonia and volatile nutrients), absorbs water, nutrient ions, and biochar provides stable refugee for microbes and compost provides immediate nutrient (David, 2014). Biochar is beneficial for growing crops and improves crop yield in acidic and highly weathered tropical field soils (Kimetu *et al*., 2008).

The potential of biochar in improving soils properties and enhancing the growth of plants was mainly done in laboratory studies, and in non woody plants, but rarely in woody plants like tree seedlings. As biochar is a recent interest of soil carbon study, the effect of biochar research on its seedlings growth was scanty. In Ethiopia, *F. albida* is a well-known parkland agroforestry tree species in some dry lands. However, its distribution is limited by poor germination capacity of the seed, and poor management that reduce its survival in areas where the sandy texture of the soil is low.

Although biochar can be a potential ingredient of nursery soil mixture in deforested areas, information is lacking about biochar effect in clay loam soils nursery sites of *F. albida*. Seeds of *F. albida* are also difficult to germinate in short period of time. Seed germination of *F. albida* is facilitated by nicking or soaking in warm and cold water (Azene, 2007). However, nicking is time taking and probable cause of seed damage. The seedlings of *F. albida* grow best in sandy soils (Joly, 1992; Coates-Palgrave, 2002; Moser, 2006). Therefore, presowing treatment of soaking seeds and method of improving the soil aeration in non-sandy soils is highly important. Accordingly, the objective of the present study was to compare pretreatment of nicking and warm and cold water stratification and early growth performance of *F. albida* tree seedlings grown in different soil mixture of bio-char.

Material and methods

Description of Faidherbia albida (Delile) A. Chev.

F. albida is synonymous with *Acacia albida* Del. (USDA, 2009). It is a deciduous legume tree that coppices readily and can grow to a large size. The indehiscent pods are ring shaped and contain 10-20 dark brown seeds, which stays viable for many years (Azene, 2007). It is well established in sandy alluvium and sandy clay in the West Africa and on alluvial soil in Eastern and Southern Africa (Joly, 1992).

F. albida is commonly found in the Middle-East and in South-East Asia, in sandy areas with 250 to 1800 mm annual rainfall and long dry seasons temperatures ranging from 6°C to 42°C (Coates-Palgrave, 2002). Stem diameter at breast height can exceed 1-2 m (Leggett *et al*., 2001). The tree can live to an age of 70 to 90 years with individuals being reported as old as 150 years (CTFT, 1989).

Study site description

The study was conducted in Gemede nursery site, close to Gunchire town of Enemorina Ener district (woreda) in Southern Ethiopia (Figure 2). The nursery site is close to a perennial river which is used for watering the site. The nursery site is surrounded by Eucalyptus plantation forest in the Eastern direction and by natural forests in all other directions. The local soil type was clay loam. The agroecology of the study site was midland with Tepid to cool submoist - plains (SM2-1), altitude: 1600-2400, latitude: 8°4'1.8"; longitude: 37°48'53"; mean annual precipitation: 1150 mm and Temperature: 18.5°C (Figure 3). Dominant woody plants are *Acacia abyssinica* Hochst. ex Benth, *Eucalyptus camaldulensis* Dehnh., *Juniperus procera* Hochst. ex Endl., *Olea species, Phoenix reclinata* Jacq., *Syzygium guineensis Willd. DC., Bersama abyssinica* Fresen., *Croton macrostachyus* Hochst. ex Delile. and *Acacia tortilis* (Forssk.) Hayne.

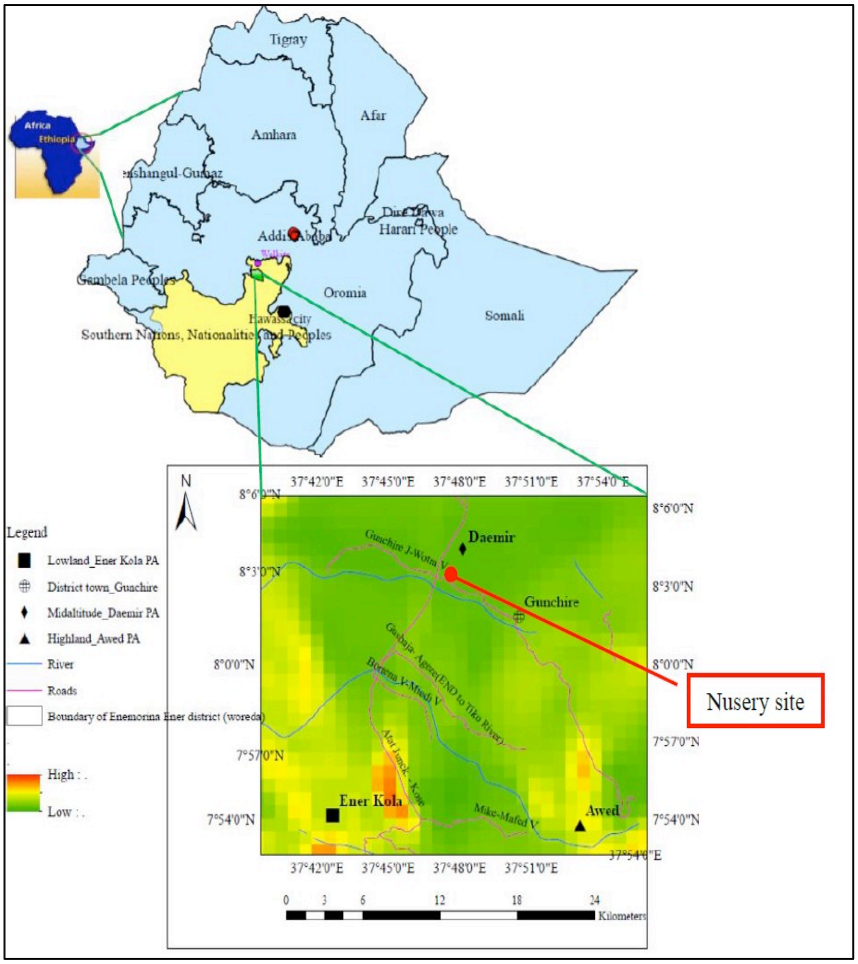


Figure 2: Location map of the study area (Author)

Climate of the study area

In 2005-2013 the mean monthly rainfall in Enemorina Ener district, Gunchire town was 21.65 to 266.5 mm, with annual mean of 1290 mm. The main rainy season is June to September. In 2005-2013, the neighboring district's maximum monthly temperature was 21.7 to 26.8°C and minimum temperature was 6.7 to 11.9°C as obtained from Ethiopian Meteorological Agency (Figure 3).

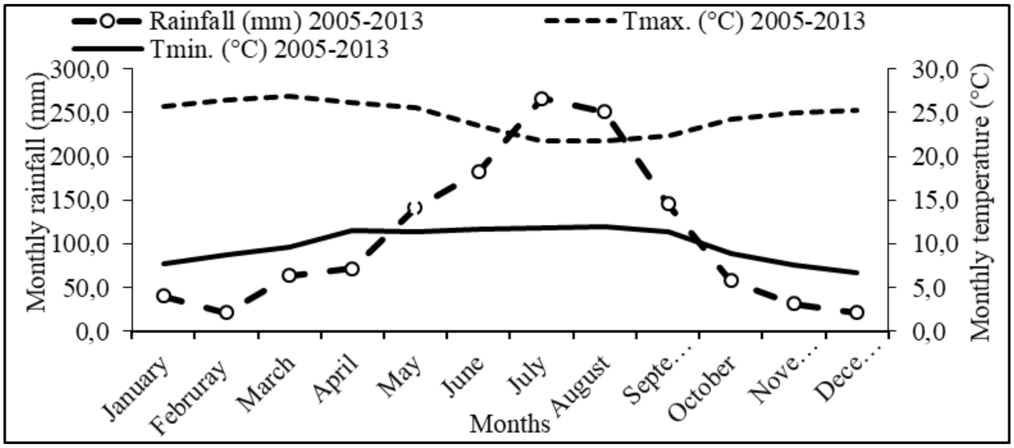


Figure 3: Rainfall and temperature (2005-2013) of the studied Gunchire town closer to the nursery site (The temperature is from neighboring district in 2005-2013).

Soil mixture preparation for seedling growing media

Three types of soil mixture ingredients were used which were obtained from the nearby area including local soil, compost, and bio-char. The compost was made from local soil, cattle dung, local grass, green leaves of *S. guineensis,* and *C. macrostachyus* and dry stalk of maize (Figure 4). First 1.2m deep, 1m wide and 2m long pit was dug. The bottom layer of the pit to the thickness of 10cm was filled with long dry maize stalk that had no moisture, then a 10cm layer of 1cm, chopped undried grasses and green leaves were added, then uniformly and equally mixed dung and local soil was added for 15cm thick layer. Then layers were repeated as depicted in Figure 4. Local soil was obtained from the eastern direction close to the Eucalyptus plantation, and cattle dung was collected from the nearby grazing land. The compost in the pit was kept for three months, about two months in one side and returned to be kept in another side in the next one month. The pit with compost was watered about 20m^3 water every second day.

Figure 4: The components mixture used in making local compost in 1.2 m deep pit (side view)

Biochar was prepared from locally available biomass feed stock that include urban waste of chat leaves (*Catha edulis*), coffee husk (*Coffea arabica*), and sawdust (*Cupressus lusitanica*). Chat leaves and coffee husk were heated at 350°C temperature and the saw dust by 300 and 350°C using pyrolysis kiln for 4hours. The local soil, compost and biochar were completely mixed at a required volume proportion, for example 3m^3 local soils with 1m^3 biochar and 1m^3 compost (as ratio 3:01:01) before filling polythene tubes of 12cm diameter and 20cm length. During polythene tube filling the mixtures were moistened by tap water and 0.125m^3 pure sand was added for each of 1m^3 local soil. Then two months old seedlings were transplanted.

Table 1. Treatments of biochar and compost preparation for nursery seedling growing soil mixtures

No.	Treatment (T) of soil mixture composition	Proportion		
		% Bio-char	% Compost	% Local soil
T1	Local soil and biochar of sawdust 350°C in ratio: 03:01	25	0	75
T2	Local soil, compost and biochar of sawdust 350°C in ratio: 03:01:01	20	20	60
T3	Local soil and biochar of chat leaves 350°C in ratio: 03:01	25	0	75
T4	Local soil, compost and biochar of chat leaves 350°C in ratio: 03:01:01	20	20	60
T5	Local soil and biochar of sawdust 300°C in ratio: 03:01	25	0	75
T6	Local soil, compost and biochar of sawdust 300°C in ratio: 03:01:01	20	20	60
T7	Local soil and biochar of coffee husk 350°C in ratio: 03:01	25	0	75
T8	Local soil, compost and biochar of coffee husk 350°C in ratio: 03:01:01	20	20	60
T9	Compost and local soil in ratio 01:01	0	50	50
T10	Local soil			100

Note: treatments 1 and 2 are sawdust at 350°C; 3 and 4 are chat leaves at 350°C; 5 and 6 are sawdust at 300°C; and 7, and 8 are coffee husk at 350°C; treatment 9 to 10 local soil and compost.

Seed germination

The seeds of *F. albida* collected from forest by Central Ethiopia Environment and Forest Research Center. About 1,200 pure, uninfected seeds were randomly sampled from the bulk of seeds received and pre-sowing treatment was made in three different ways. One treatment group of 400 seeds were nicked by file, the other 400 seeds were warm and cold water stratified and occasionally shacked for 24hours and the rest were not treated. Then all the seeds were buried in seed bed at the depth down the diameter of each seed. The seedbeds were covered with grasses mulch to avoid direct sunlight reaching the seeds, and watered daily. At day 60 after sowing, the germinated seeds were counted and the percentage was calculated. Germination of seed was considered when the radicle extended 1 cm beyond the testa.

Seedling survival and growth performance

The survival and growth performance of eight months (December 2019 to July 2020) and 20 months (December 2019 to July 2021) seedlings were measured the root collar diameter (RCD), stem height (H), and survival. The RCD was measured by graduated caliper and H by graduated ruler. The survival of 25% the seedlings in each treatment was also counted.

Data analyses

The generalized linear model (GLM) and partial correlation procedure of SPSS (SPSS 20 Copyright: SPSS Inc.) was employed for analysis of variance (ANOVA) and correlation. The analysis variance of means of seedlings survival, root collar diameter, and stem height was determined using Student-Newman-Keuls test based on the following fixed effect model:

$$Y_{ij} = \mu + P_i + e_{ij}$$

Where Y_{ij} is seedling trait of j^{th} replication of the i^{th} treatment, μ is the overall mean, P_i the effect due to i^{th} treatment (i = 1 . . . 10) and e_{ij} is the error.

Results

Seed germination

The number of germinated seeds in the case of warm and cold water stratification was 76% while that of the nicked treatment was 45%. This indicated the ability of warm and cold water stratification in supplying optimum moisture and air to initiate the germination of the seeds of *F.albida* (Table 2). The use of stratification was preferable not only in increasing the number of seeds germinated but also to reduce the tedious work of nicking seeds and risk of damaging the embryo of the seed.

Table 2. Germination of F.albida seed under different presowing treatment

Pre sowing treatment		
Nicking (%)	Warm and cold water stratification (%)	No treatment (%)
45	76	17

Growth performance of seedlings

The survival, root collar diameter (RCD) and stem height (H) growth of seedlings of *F.albida* were statistically different under different soil mixture treatments at p<0.05. In year 1, the effect of soil mixtures on survival and root collar diameter growth was greater than the corresponding height growth because the significance level of survival and RCD was P<0.001 while that of height was P<0.002. However, in year two, the stem height growth was not significant among the treatments. Therefore, root collar diameter was the most important parameter for the seedlings that showed the effect of soil mixture treatments (Table 3).

Table 3. The analysis of variance of root collar diameter and height growth of F. albida seedlings in the first and second year

YEAR ONE						
		SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
Survival (%) * Treatment	Between Groups	6774.967	9	752.774	1881.935	.000
	Within Groups	8.000	20	.400		
	Total	6782.967	29			
RCD (cm) * Treatment	Between Groups	6.61	9	0.735	181.318	0
	Within Groups	1.01	250	0.004		
	Total	7.62	259			
Stem height (cm) * Treatment	Between Groups	154.63	9	17.181	3.052	0.002
	Within Groups	1407.52	250	5.63		
	Total	1562.15	259			
YEAR TWO						
		SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
Survival (%) * Treatment	Between Groups	8327.200	9	925.244	62.517	.000
	Within Groups	296.000	20	14.800		
	Total	8623.200	29			
RCD (cm) * Treatment	Between Groups	7.383	9	0.82	156.534	0
	Within Groups	1.31	250	0.005		
	Total	8.693	259			
Stem height (cm) * Treatment	Between Groups	48.777	9	5.42	1.243	0.269
	Within Groups	1089.909	250	4.36		
	Total	1138.686	259			

Root collar diameter of seedlings

In the first year, the greatest RCD growth was obtained from treatment 10 (T10) soil mixtures that composed only local soil, about mean RCD of 0.84cm, ranging from 0.66 to 1.03cm. Comparatively, the soil mixtures that composed of local soil and biochar of sawdust 300°C in ratio: 03:01 (T5) or 25% biochar of sawdust 300°C; compost and local soil in ratio 01:01 (T9) or 50% compost; and simple local soil (T10) or 100% local soil showed relatively better growth of RCD of *F.albida* seedlings (Figure 5). The minimum growth of RCD was obtained in treatment 2 (T2) soil mixtures that composed of local soil, compost and biochar of sawdust 350°C in ratio: 03:01:01 or 20% bio-char, about 0.37cm RCD growth. In statistical analysis of the grouping in the growth of RCD was obtained in decreasing order of group 1: T10, T5 and T9; group 2: T4; group 3: T7, T8, T6; group 4: T3; and the least RCD growth was obtained in group 5: T1 and T2 (Figure 5). In the second year, the greatest mean root collar diameter growth about 1.09cm was obtained from treatment 1 (T1) that composed the mixture of local soil and biochar of Sawdust 350°C in ratio: 03:01, followed by the local soil and the minimum about 0.65cm from treatment 3, (T3) that composed the mixture of local soil and biochar of chat leaves 350°C in ratio: 03:01. This showed the need for additional growth time and observation to get clear distinction about the effect of biochar on the growth of the seedlings.

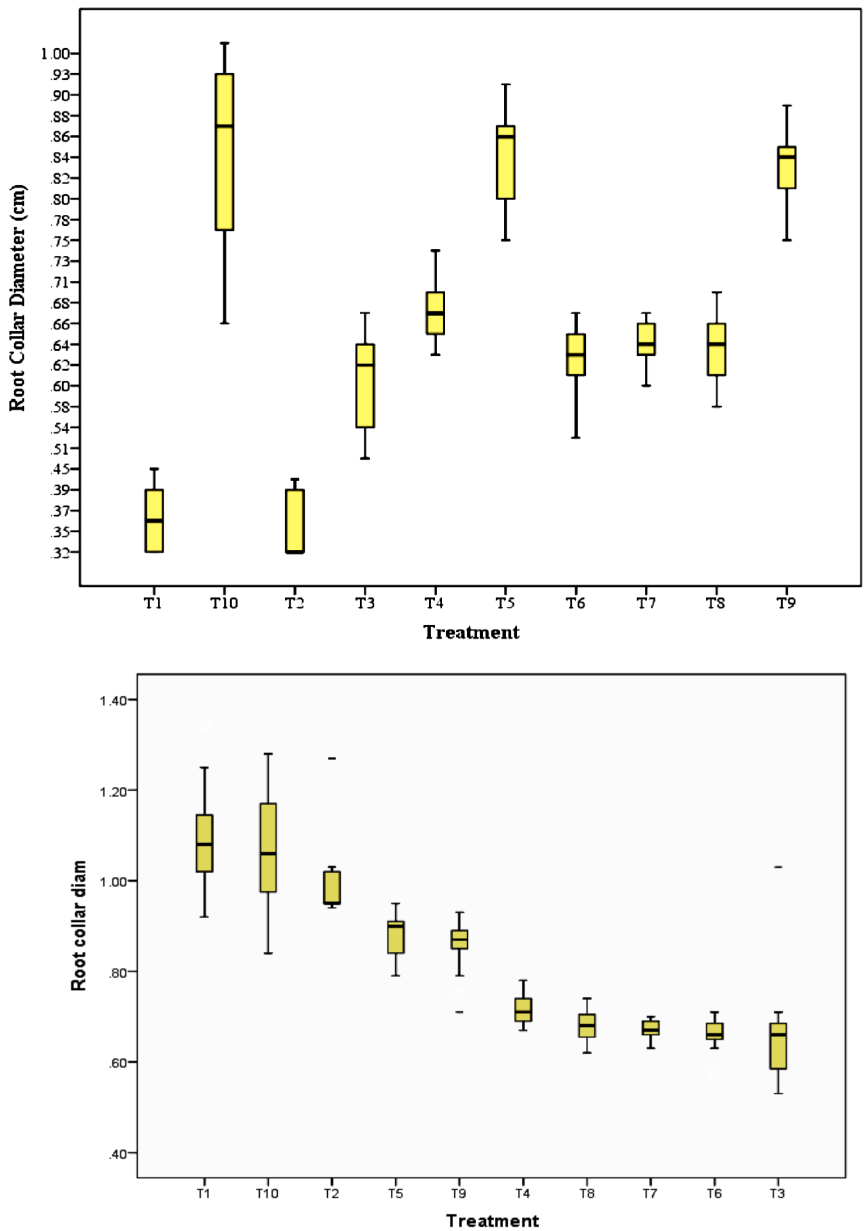


Figure 5: Root collar diameter growth of F. albida seedlings under bio-char, compost and local soil mixture in eight months (top) and 20 months (bottom).

T 1: Local soil and Biochar of Sawdust 350°C in ratio: 03:01; T 2: Local soil, Compost and Biochar of Sawdust 350°C in ratio: 03:01:01; T 3: Local soil and Biochar of Chat leaves 350°C in ratio: 03:01; T 4: Local soil, Compost and Biochar of Chat leaves 350°C in ratio: 03:01:01; T 5: Local soil and Biochar of Sawdust 300°C in ratio: 03:01; T 6: Local soil, Compost and Biochar of Sawdust 300°C in ratio: 03:01:01; T 7: Local soil and Biochar of Coffee husk 350°C in ratio: 03:01; T 8: Local soil, Compost and Biochar of Coffee husk 350°C in ratio: 03:01:01; T 9: Compost and local soil in ratio 01:01; T 10: Local soil.

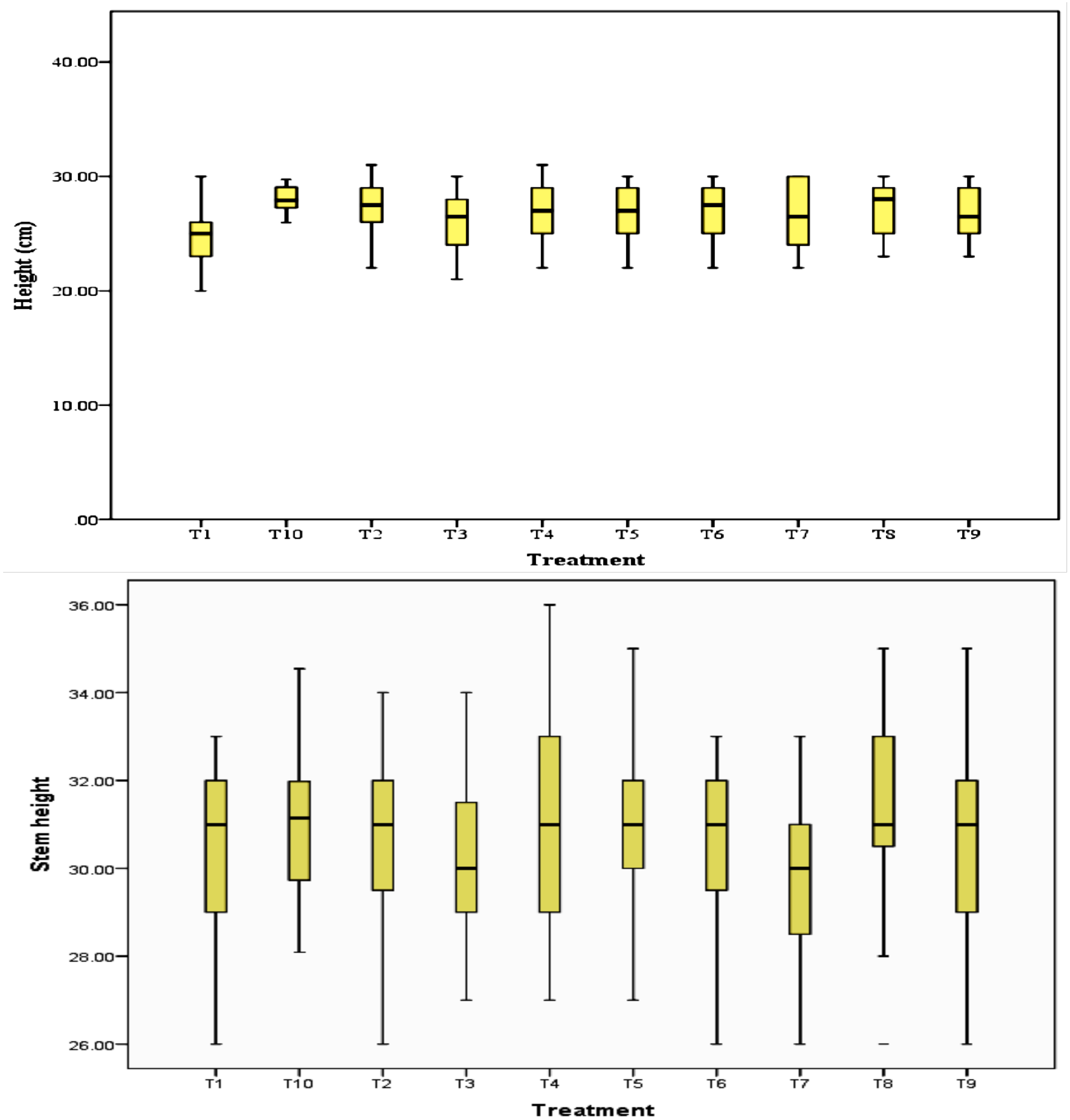


Figure 6: The height growth of F. albida seedlings under bio-char, compost and local soil mixture in eight months (top) and 20months (bottom)

T 1: Local soil and Biochar of Sawdust 350°C in ratio: 03:01; T 2: Local soil, Compost and Biochar of Sawdust 350°C in ratio: 03:01:01; T 3: Local soil and Biochar of Chat leaves 350°C in ratio: 03:01; T 4: Local soil, Compost and Biochar of Chat leaves 350°C in ratio: 03:01:01; T 5: Local soil and Biochar of Sawdust 300°C in ratio: 03:01; T 6: Local soil, Compost and Biochar of Sawdust 300°C in ratio: 03:01:01; T 7: Local soil and Biochar of Coffee husk 350°C in ratio: 03:01; T 8: Local soil, Compost and Biochar of Coffee husk 350°C in ratio: 03:01:01; T 9: Compost and local soil in ratio 01:01; T 10: Local soil.

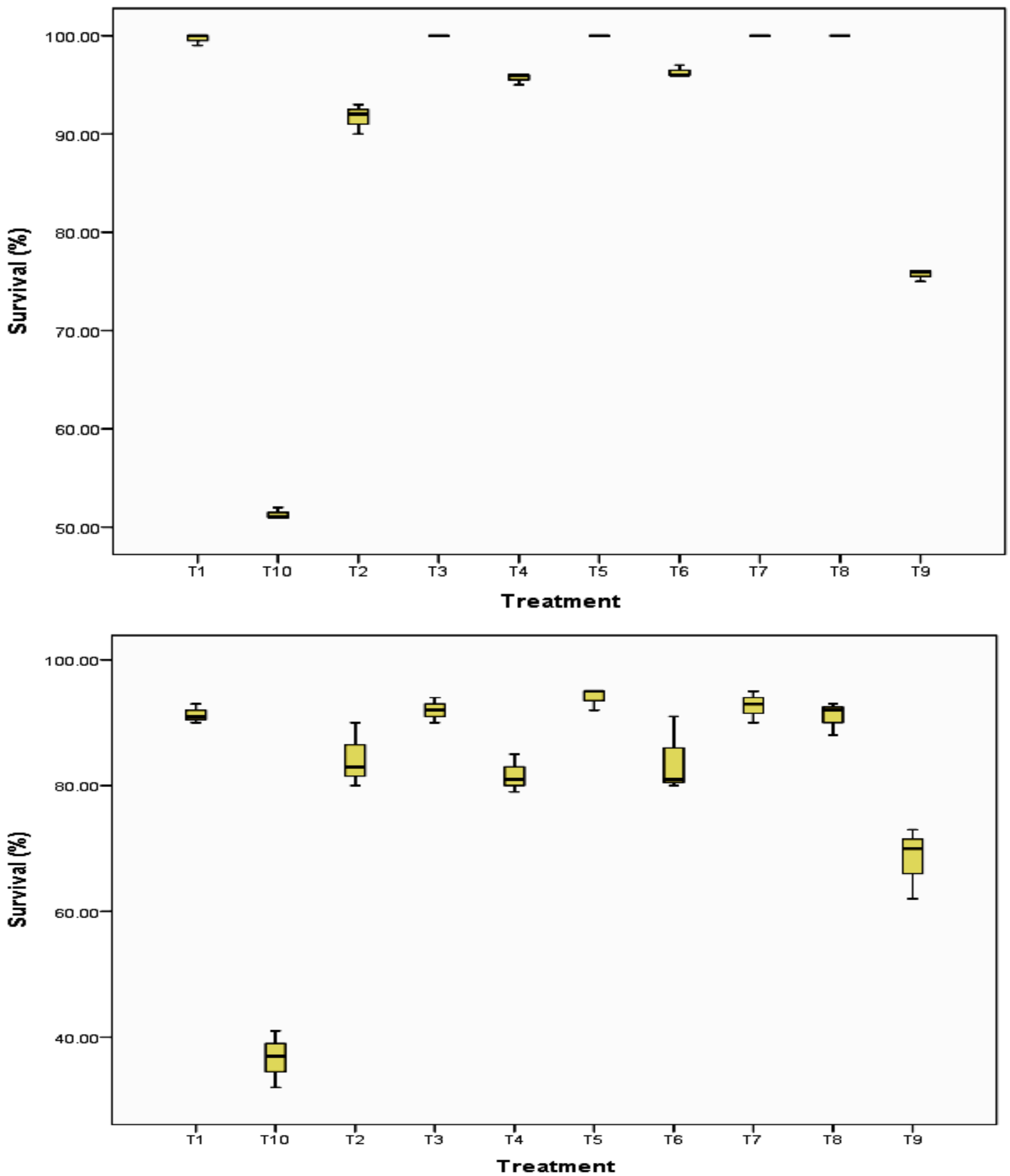
Seedlings height

In the first year, the greatest height growth was obtained at treatment 10 (T10) soil mixtures that composed only local soil, about mean height of 28cm, ranging from 25.96 to 29.73cm. Comparatively, the soil mixtures that composed of local soil, biochar and compost from treatment 2 up to treatment 10 (T2 to T10) showed relatively better growth of height of *F. albida* seedlings. That is the minimum growth in height was obtained in treatment 1 (T1) soil mixtures that composed of local soil and biochar of sawdust 350°C in ratio: 03:01, about mean height of 24.85cm growth, ranging from 20 to 30cm (Figure 6). This indicated the necessity of adding compost in the soil mixtures of biochar for seedling growth.

In the second year, the greatest mean stem height growth about 31.2cm was obtained from treatment 8 (T8), that composed local soil, compost and biochar of coffee husk 350°C in ratio: 03:01:01, and the minimum about 29.7cm from treatment 7 (T7) that composed of local soil and biochar of coffee husk 350°C in ratio: 03:01. That is the presence of compost in the mixture improved the height growth of seedlings.

Survival of seedlings the first and second year

The average survival of seedlings of *F. albida* varied among the soil mixtures. The maximum survival about 100% was observed in many of the soil mixtures including local soil and biochar of sawdust 350°C in ratio: 03:01 (T1); local soil and biochar of chat leaves 350°C in ratio: 03:01 (T3); local soil and biochar of sawdust 300°C in ratio: 03:01 (T5); local soil and biochar of coffee husk 350°C in ratio: 03:01 (T7); and local soil , compost and biochar of coffee husk 350°C in ratio: 03:01:01 (T8) (Figure 7 and Figure 8). The soil mixtures that had biochar showed better survival than those without bio-char. The local soil (T10) which was used without any other mixture showed the lowest survival rate of about 51% (Figure 7). Therefore, the local soil is poor to support the survival of seedlings and then additional ingredient is needed. In the second year in the nursery stay, the highest survival about 94% was obtained from the mixture of local soil, saw dust biochar at 300°C (with proportion of 3:01) in treatment 5 (T5), the lowest about 36.7% was obtained from local soil (T10) as shown in Figure 7. This also emphasized the need to use additional ingredients in the nursery soil mixtures.



T 1: Local soil and Biochar of Sawdust 350°C in ratio: 03:01; T 2: Local soil, Compost and Biochar of Sawdust 350°C in ratio: 03:01:01; T 3: Local soil and Biochar of Chat leaves 350°C in ratio: 03:01; T 4: Local soil, Compost and Biochar of Chat leaves 350°C in ratio: 03:01:01; T 5: Local soil and Biochar of Sawdust 300°C in ratio: 03:01; T 6: Local soil, Compost and Biochar of Sawdust 300°C in ratio: 03:01:01; T 7: Local soil and Biochar of Coffee husk 350°C in ratio: 03:01; T 8: Local soil, Compost and Biochar of Coffee husk 350°C in ratio: 03:01:01; T 9: Compost and local soil in ratio 01:01; T 10: Local soil.

Figure 7. The survival of F. albida seedlings under bio-char, compost and local soil mixture in 8 months (top) and 20months (bottom)

Figure 8: Seedling growth under different soils mixture, 8 months old (left) and 20 months old (right)

In the first year of eight months of survival and growth of seedlings in the nursery, the mixture of local soil and biochar of sawdust 300°C in ratio 03:01 (T5) showed the greatest performance followed by the mixture of local soil, compost and biochar of coffee husk 350°C in ratio 03:01:01 (T8); local soil and biochar of coffee husk 350°C in ratio: 03:01 (T7); local soil and biochar of chat leaves 350°C in ratio 03:01 (T3); and the mixture of local soil and biochar of sawdust 350°C in ratio 03:01 (T1). The lowest performance was observed from local soil (T10) and the mixture of compost and local soil in ratio 01:01 (T9). In the second year of 20 months of survival and growth of seedlings in the mixture of local soil and biochar of sawdust 300°C in ratio 03:01 (T5) showed the greatest performance. The local soil (T10) and the mixture of compost and local soil in ratio 01:01 (T9) showed lowest performance.

Correlation of the growth parameters of seedlings

The survival and height growth of the seedling was correlated with the root growth. Moreover, the root collar diameter was correlated with the root length at P=0.024 which is P< 0.05 probability level (Table 4). The root to shoot ratio of the seedlings was ranged from 0.47 to 0.51, the lowest in soil mixture of local soil, compost and biochar of sawdust 350°C (T2) and the highest in compost and local soil (T9). This indicated that local soil was necessary for the immediate growth of seedling roots which was the media before transplanting seedlings.

Table 4. Correlations analysis of the growth of different parts of seedlings of F.albida

		STEM HEIGHT (CM)	SURVIVAL (%)	ROOT LENGTH
Root Collar Diameter(cm)	Pearson Correlation	0.608	-0.473	.700*
	Sig. (2-tailed)	0.062	0.167	0.024
Height (cm)	Pearson Correlation		-0.574	.786**
	Sig. (2-tailed)		0.083	0.007
Survival (%)	Pearson Correlation			-.733*
	Sig. (2-tailed)			0.016

**. Correlation is significant at the 0.05 probability level (2-tailed).*
***. Correlation is significant at the 0.01 probability level (2-tailed).*

Discussion

Successful initial seed germination of *F. albida* determines the vigorousity and healthiness of seedlings. Fast germination results in greater number of vigorous seedlings with strong root and shoots development (Corbasson *et al*., 1986; Evans and Blazich, 1999). About 76% of the seeds from warm and cold water stratification treatment were germinated, which was greater than the other studies conducted elsewhere in Dangasuk *et al*. (2001) about 69.7%, and lower than the study of Diémé *et al*., (2025) by soaking in 98% sulphuric acid for seven days that germinated about 100%; but within the range of the study made by Azene (2007) about 60-90%. Therefore, warm and cold water stratification was the best treatment for softening the seed coat and initiation of the germination of *F. albida* seeds as studied in Evans and Blazich (1999). However, the local people personally communicated in nursery site had no warm and cold water stratification knowledge in sowing the seeds of *F. albida* and this simple technique should be introduced. The number of seeds germinated by the locally practice of nicking was lower either because of damage or inappropriateness. Similarly, laboratory test of the use of the locally available warm and cold water stratification 24 hours with occasional shaking is needed to confirm the potential of seed germination of *F. albida* because at the nursery beds some seedlings could be lost or damaged without being counted. It was reviewed that using biochar also improves the germination of seeds (Karim *et al*., 2025) which should be tested for *F.albida* seeds in the future.

Compost and manure are options in the place of natural forest soils, in soil mixture preparation for nursery seedling growth. Moreover, it is found that biochar is a possible ingredient in nursery soil mixture so as to supplement the forest soil and sand shortage. Then biochar can be used in the absence of sand or as supplementary to grow sandy soil demanding *F. albida* tree (Joly, 1992). Biochar is a fine-grained and porous charcoal which supplies aeration for root growth. Previous studies confirmed that biochar and compost mixtures have synergistic benefits of supporting the growth of seedlings (Dias *et al*., 2010; Karim *et al*., 2025).

In eight months, the average growth in root collar diameter (RCD) from 0.39 to 0.84 and height from 25 to 28 cm observed from seedlings of *F. albida* were lower than the other studies conducted elsewhere in Africa by Dangasuk *et al*. (2001). Lower growth of seedlings at early stage could be observed in biochar application because of imbalances in temporary levels of pH, volatile matter, and/or nutrient associated with fresh biochar (McClellan *et al*. 2007). The impact of biochar on seedlings increases as the biochar interact with soil through time. The effect of the soil mixtures on the root collar diameter growth was greater than the corresponding height growth (Figure 5 and 6). The soil treatment that contained only local soil was the best in increasing the growth of RCD and height of few seedlings of *F. albida*. Those well grown seedlings are naturally favoured within the same soil mixture which could be attributed to the inherent characteristics of seedlings and therefore, require further study. Soil mixture containing 25% biochar of saw dust 300°C, 50% compost with local soil and 100% local soil showed better RCD growth than the other soil mixtures as stated in Hunt *et al*. (2010). Moreover, in 20 months growth of seedlings, the height growth to 31.2cm and root collar diameter to 1.1cm was favourable for planting out, which showed the effect of biochar as compared with the local soils of height growth 29.7cm and root collar diameter to 0.65cm.

The temperature level of pyrolysis saw dust biochar making of 300°C was better than the 350°C in RCD development and survival, because of the susceptible of the biochar to be converted to ash at the higher temperature (Figure 5 and Figure 6).

Local soil mixture treatment (T10) was better for the early growth of RCD and height of seedlings of *F. albida* (Figure 5 and Figure 6), however, it highly reduced the survival of seedlings, almost by half (Figure 7). Soil mixtures that contained biochar improved the survival of seedlings as studied by Kimetu *et al*. (2008), which is attributed to better moisture retention capacity of biochar (Rakib *et al*., 2025). All seedlings of *F. albida* grown in mixtures of biochar survived above 90%. Therefore, mere local soil is poor to support the survival of *F. albida* seedlings and then additional ingredient is needed. Biochar is easily obtainable from pyrolysis of local biomass materials and not as inaccessible as sand or other soil mixture ingredients. Therefore, biochar should be used to improve the survival of seedlings. Moreover, the local soils are depleting through time and lack sufficient nutrient to support the growth of seedlings (Simons, 1999), but biochar had increased the survival and then expected to increase growth of seedlings through time as stated by David (2014). The 25% biochar in soil mixtures resulted in 100% survival better than the lower proportion of biochar (Figure 7). Therefore, this study confirmed the proportion 25% biochar is better for survival of seedlings as studied in Hunt *et al*. (2010). The survival and height growth of the seedling was correlated with the growth of root, and therefore, the improvement of survival of seedling of *F. albida* by biochar is an indicator of improvement of growth.

Conclusion and recommendation

A greater number of *F. albida* seeds germinated under the presowing treatment of warm and cold water stratification with occasional shaking for 24 hours instead of the usually known nicking which could damage the embryo. Nicking is also tedious and time consuming when compared with the stratification. The number of seedlings of *F. albida* grown in local soil mixture generally showed better early growth than the seedlings in biochar mixed soils. The overall performance of on the survival and growth of the eight and 20months observation revealed that the mixture of local soil and biochar of sawdust 300°C in ratio of 03:01 (T5) was the best followed by the mixture of local soil, compost and biochar of coffee husk 350°C in ratio of 03:01:01 (T8). The least performance on the survival and growth was obtained from local soil (T10) followed by compost and local soil in ratio of 01:01 (T9), which showed that through time the compost decomposed and the mixture maintained the character of local soil. Therefore, biochar addition was highly important for the survival of seedlings of *F. albida* because of the moisture and nutrient adherent properties of bio-char. However, it is generally believed that seedlings grown under biochar mixture are expected to have better future growth because they showed greater number of survival than mere local soil. Biochar addition that share around 25% of the potted soil mixture comprising local soil, and compost can easily be obtained by pyrolysing local biomass material in the absence of forest soil. There is short supply of forest soils in nurseries because of deforestation and land use change. Moreover, local biomass use to make biochar is a way to dispose waste from agricultural and wood processing residues. The biochar made possible the growth of *F. albida* in dry land clay soils; therefore, biochar improved the clay loam local soil and provide aeration to the soil. Biochar also has soil carbon increment potential that should be used to mitigate emission of greenhouse gases because biochar is not easily decomposing when compared with easily decomposing raw biomass like compost and dung. However, biochar should be used in combination with fast decomposing so as to supply the seedlings with readymade nutrient. The place of getting biochar in rural areas is diverse such as residues from charcoal making areas (fine dusty charcoals can be used as a biochar for soil amendment), and pyrolysing local biomass of agricultural and wood residues or even urban nontoxic food and paper wastes. Therefore, local seedling raising nursery workers should be trained on the ways of local biochar preparation. Moreover, it is highly recommendable to study the nutritive content of the different biomasses that to be used for biochar making in addition to the growth of seedlings.

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