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Research article

Evaluation of soil seed bank-vegetation and regeneration potential of *Tectona grandis* L. f. plantation (Taungya farm) in Akure forest reserve, Ondo State, Nigeria

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Abstract: The study investigated the germinable soil seed bank along three soil depths in a *Tectona grandis* plantation (Taungya farm) in Akure forest reserve, Ondo State, Nigeria. Three sampling plots of 50 by 50 m using systematic line transect were laid. Composition of the established plantation was assessed by taking fifteen different soil samples (0–3, 3–6 and 6–9 cm depth) at each plot and the seed banks composition was determined by greenhouse germination over a period of 3 months. In the soil seed bank seedling, the Shannon-Wienner index had 2.8. The result of other biodiversity indices were; 2.8 for species evenness value. For Margaref's index of species richness, Taungya farm had value of 123.9. Species abundance in seedlings germinated from soil seed bank was observed as 349 species from Taungya farm. On the other hand, sapling densities, the common tree saplings in this plantation were *Baphia nitida*, *Ficus exasperata* and *Rauvolfia vomitoria.* The species abundance from the sapling was also observed in Taungya farm with the total of 27 seedling m^{-2}.The value in the other biodiversity indices; Margalef's index of species richness (4.19), Pielou's species evenness index (0.9) and Shannon - Weiner index (2.97). The similarity between the composition of the seed bank flora and that of the above vegetation (sapling) and established plantation was low throughout the study. The seed bank density and diversity for most species in this study were found to be greatly influenced by environmental factors. At low soil depth layer, richness is greater and herbaceous species dominate while at higher soil depth layer (0–9 cm) species richness diminishes and less dominates.
Keywords: Plantation - Seedling - Regeneration - Soil seed bank - Diversity - Taungya farm.

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INTRODUCTION

It's becoming imperative in this era to observe that biodiversity losses are becoming a serious phenomenal to be tackled in this global warming and biodiversity conservation as one of the measured put in place to solve these biodiversity losses is partially prioritize in the different ecosystem due to increase in global demand for wood products. To justify this, about 5 % of world's total forest area, about 34 % of global industrial wood is sourced from plantations, with countries like New Zealand, South Africa, Chile, Brazil, Japan and Zambia deriving 50–100 % of their industrial wood from plantations (FAO 1999, Sutton 1999, FAO 2001). For similar reasons, Onyekwelu *et al.* (2010) reported that large scale plantation establishment with predominantly *Tectona grandis* L. f. and *Gmelina arborea* Roxb. ex Sm. started in Nigeria during the 1960s until 1979, these plantations were established through the Taungya system of farming. Based on this observation, it is believed that the global forest plantation area has continued to grow as many countries move to establish sustainable sources of wood to meet their increasing demand for wood and pulp (Onyekwelu *et al.* 2010). However, the use of plantation is to restore diverse tree vegetation seems paradoxical, but research helps clarify why this use of tree plantations may be an effective tool for land and vegetation rehabilitation. Studies have shown that

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plantations can speed the recovery of biodiversity and promote woody species regeneration on re-growth secondary forest lands in tropical regions by speeding up forest succession processes, an increase of soil fertility and improving site conditions (Bernhard-Reversat 2001, Cusack & Montagnini 2004, Bajpai *et al.* 2012). Kothandaraman *et al.* (2017) reported that understorey vegetation is known to play a crucial role in maintaining ecosystem dynamics. They further explained that the understorey vegetation stocks considerable levels of nutrients in the forest, especially during the early stages of stand development (Perala & Alban 1982, Augusto *et al.* 2003). Therefore, the aim of this study is to examine and evaluate soil seed bank, species composition and regeneration potential of Taungya farm as land-use types in Akure Forest Reserve, Ondo State, Nigeria.

MATERIALS AND METHODS

The study was carried out in a *Tectona grandis* plantation located in Akure forest reserve, Obada, Owenna local government area of Ondo State, Southwest Nigeria at Latitude 7º 16′40.76″ N and longitudes of 5º 2′12.94″ E. The climate of the area is humid sub-tropical. The mean annual temperature is about 26ºC (minimum 19ºC and maximum 34ºC) 9 months annually for the rainy season which is between March and November (2500 mm bimodal rainfall pattern) while the dry seasons last for 3 months, between the month of December and February. (Adekunle *et al.* 2013). The soil samples were collected in November Dry season 2016 and were under study still June Raining season 2017.

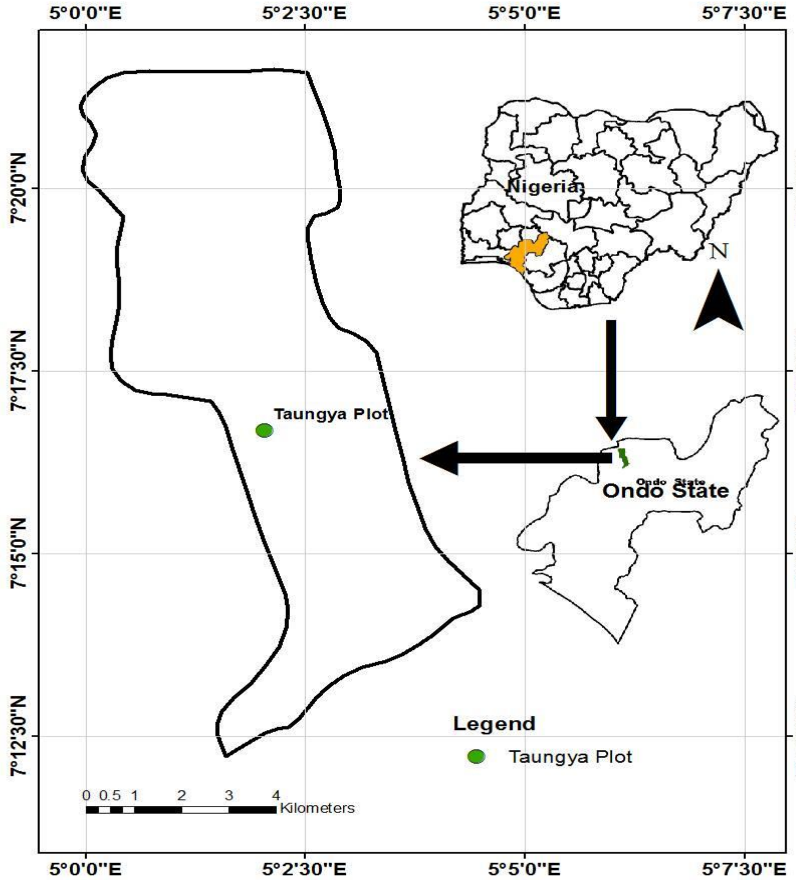

Figure 1. Map showing site location in Akure forest reserve.

Sampling technique and selection of sample plots

The laying of the plots was carried out using the systematic line transects. A 500m transect was centrally located in the forest types where three sample plots of 50 m × 50 m were laid in the alternate side. In each sample plot, all trees with Diameter at Breast Height (DBH) ≥10 cm was tagged and identified to ascertain tree species diversity. In addition, the DBH of all the trees in each plot was measured.

Soil seed bank assessment

A smaller plot of 1 m × 1 m (100 cm^2), were also located for the enumeration of species saplings and wildling. The DBH (≥1cm) was measured using an electronic caliper to study the species variation of early colonizer among the forest types. Soil samples (soil seed bank) were collected at 3 different depths of 0–3 cm, 3–6 cm and 6–9 cm of successive layers from five locations per plot in the forest type using a hand trowel of self- made calibration. The samples were put in polythene bags, labeled. Soil composite were made out of the soil samples collected from the location after thoroughly merged them. The soil seed bank from each location and depth were removed of roots and pebbles and stored in a potting medium of the perforated plastic tray, covered with a cotton cloth to keep the sample moist always (Fig. 2). The sample was taken to the greenhouse at the Department of Forestry and Wood Department's nursery, FUTA where they were incubated to stimulate seed germination. Emerging and readily identifiable seedling was counted, recorded and discarded. Every two weeks, the soil samples were stirred to stimulate seed germination and to encourage seed sprouting during the period of the project. The germinated seedlings were countered and identified. For data analyses, appropriate formulae were involved in basal area computation. Biodiversity indices were adopted to determine species abundance and evenness and to compare community diversity. Descriptive statistics were used to determine the density of trees, shrubs, saplings, seedlings and abundance of soil seed bank distribution.

Figure 2. Showing the soil seed emergence.

Data analysis

Forest structure analysis: Basal area of all trees in the sample plots were calculated using the formula:

$$BA = \frac{\pi D^2}{4}$$

Where, BA= Basal area (m^2); D= Diameter at breast height (cm); n= pie (3.142).

Biodiversity Indices: Various indices calculated in the study as follows,

(i) Relative density (%) of each species was computed using the following equation:

$$RD = \frac{n_i}{N} \times 100$$

Where, RD= Relative density of the species; n*i*= Number of individuals of species *i*; N= Total number of all individual trees.

(ii) Species relative dominance (%) of each species was estimated using the following equation:

$$RD_O = \frac{\sum Ba_i \times 100}{\sum Ba_n}$$

Where, Ba_i= Basal area of individual tree belonging to species *i*; Ba_n= Stand basal area.

(iii) Tree species diversity; this followed the method described by the following equation:

Shannon-Wiener diversity index:

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i)$$

Where, H'= Shannon diversity index; S= Total number of species in the community; p_i= Proportion S (species in the family) made up of the *i*th species; ln= Natural logarithm.

(iv) Species evenness (E), in each community Shannon's equitability equation adopted:

$$E_H = \frac{H^{'}}{H_{Max}} = \frac{\sum_{i=1}^{S} P_i \ln(P_i)}{\ln(S)}$$

(v) Family Importance Value (FIV): This was used to estimate a family's share in the forest community. This is the sum of the relative dominance (RD_o), relative density (RD) divided by 2.

$$FVI = \frac{(\text{RD} + \text{RDo})}{2}$$

(vi) Importance Value Index (IVI): The sum of the RD and RDo divided by two gave the importance value index for each species:

$$IVI = \frac{(\text{RD x RDo})}{2}$$

RESULT

Understorey species composition and density

Table 1, shows 21 families distributed into 21 species and 18 genera in the Taungya farm. A total of 58.44 stem ha^{-1} was recorded as mean density in Taungya farm representing the 21 species (10 herbaceous species, 5 trees, 5 climbers and 1 grass). The herbaceous had most dominated species in the site which only accounted for 61.73%, the climber had 20.06%, and the tree had 15.32% while grass had the least value (2.909%). The herbaceous found here included; *Chromolaena odorata* (L.) R. M. King & H. Rob., *Commelina erecta* L. subsp. *erecta*, *Cyathula prostrata* (L.) Blume, *Palisota ambigua* (P. Beauv.) C. B, *Palisota hirsuta* (Thunb.) K. Schum, *Phyllanthus amarus* Schum. & Thonn., *Phyllanthus capillaris* Schum. & Thonn, *Physalis angulata* L., *Spigelia anthelmia* L., *Sida acuta* Burm.f., and *Xanthosoma mafaffa* Schott. The woody species were *Baphia nitida* Load. and *Ficus exasperata* Vahl while the only grass present in the site was *Panicum maximum* Jacq. Between two and three species dominated the understorey of this site, which together accounted for a relative density (RD) of over 46%.

Table 1. Understory Species Diversity and Abundance in the study areas.

Understorey Species		Ha^{-1}	Diameter	Relative Density
Baphia nitida Load.	Tree sapling	1	1.18	2.019
Chromolaena odorata (L.) R. M. King & H. Rob.	Herb	2	2.43	4.158
Cissus kouandeensis A. Chev.	Climber	1	1.23	2.105
Commelina erecta L. subsp. *erecta*	Herb	1	3.99	6.828
Cyathula prostrata (L.) Blume	Herb	1	2.34	4.004
Dioscorea alata L.	Climber	1	1.50	2.567
Ficus exasperata Vahl	Tree sapling	2	3.76	6.434
Icacina trichantha Oliv.	Shrub sapling	1	2.11	3.611
Momordica charantia L.	Climber	1	3.01	5.151
Palisota ambigua (P. Beauv.) C. B.	Herb	1	2.77	4.740
Palisota hirsuta (Thunb.) K. Schum.	Herb	1	2.30	3.936
Panicum maximum Jacq.	Grass	1	1.70	2.909
Passiflora foetida L.	Climber	2	4.98	8.522
Phyllanthus amarus Schum. & Thonn.	Herb	1	1.05	1.797
Phyllanthus capillaris Schum. & Thonn.	Herb	1	2.40	4.107
Physalis angulata L.	Herb	2	6.72	11.500
Rauvolfia vomitoria Afzel	Shrub sapling	1	1.90	3.251
Sida garckeana Polak	Herb	1	1.10	1.882
Sida urens L.	Climber	1	1.00	1.711
Spigelia anthelmia L.	Herb	1	2.22	3.799
Xanthosoma mafaffa Schott	Herb	3	8.75	14.973
	Total	**27**	**58.44**	**100**

The common understorey species in this plantation were; *Baphia nitida*, *Rauvolfia vomitoria*. The results of diversity measurements in the understorey species (sapling) and soil seed bank related to species abundance, Shannon Wiener, Simpson's index, species richness and the species evenness measures in the plantation (Taungya farm) were shown in table 2. For understorey species, Shannon's Species Diversity Index showed that the plantation (Taungya farm) had the following diversity (H= 2.97), Margalef's index of species richness (4.19), Pielou's Evenness Index revealed that the plantation stand (Taungya farm) had 0.9 in species distribution. The plantation had a Simpson index value of 0.94 and a species abundance of 25 in the study.

Table 2. Vegetation parameter measured in Three Study Sites in Akure Forest Reserve.

Understorey Species	**Value**
Numbers of Species	21
Numbers of Families	17
Number of Genus	18
Simpson's index	0.94
Species richness	4.19
Species evenness	0.90
Shannon wiener	2.97
Abundance (m^2)	27
SEEDLING	
Numbers of Species	21
Numbers of Families	17
Number of Genus	21
Simpson's index	0.98
Species richness	123.90
Species evenness	2.84
Shannon wiener	2.84
Abundance (m^2)	349
WOODY SPECIES	
Woody species	6
Density of Stem species (ha^{-1})	104
Basal area (m^2 ha^{-1})	7.831

Table 3 shows that total of 21 plant species were identified in all the three depths studied. Both 0–3 cm and 3–6 cm depths had a significantly higher (20) and (21) abundance of plant species than 6–9 cm depth (10). Only ten (10) plant species were observed and common in all the three depths investigated which includes; *Amaranthus viridis* L., *Cyathula prostrata*, *Momordica foetida* Schum. & Thonn., *Euphorbia hirta* L., *Spigelia anthelmia*, *Peperomia pellucida* (L.) H.B. & K., *Panicum maximum*, *Trema guineensis* (Schum. & Thonn) Ficalho, *Laporteaa estuans* (L.) Chew, *Pouzolzia guineensis* Benth. Other species were found either in one depth or two depths.

Table 3. Plant Species abundance in the Seed Bank of Taungya farm at 0–3 cm, 3–6 cm and 6–9 cm.

Name	**Family**	**Habit**	**0–3 cm**	**3–6 cm**	**6–9 cm**
Clerodendrum paniculatum L.	Acanthaceae	S	✓	✓	
Amaranthus viridis L.	Amaranthaceae	H	✓	✓	✓
Xanthosoma mafaffa Schott	Araceae	H	✓	✓	
Chromolaena odorata (L.) R. M. King & H. Rob.	Asteraceae	H	✓	✓	
Cyathula prostrata (L.) *Blume*	Amarnthaceae	H	✓	✓	✓
Cnestis ferruginea DC.	Connaraceae	S	✓	✓	
Momordica foetida Schum. & Thonn.	Curcubitaceae	C	✓	✓	✓
Dioscorea preussii Pax	Dioscoreaceae	C	✓	✓	
Euphorbia hirta L.	Euphorbiaceae	H	✓	✓	✓
Phyllanthus capillaris Schum. & Thonn.	Euphorbiaceae	H	✓	✓	
Solenostemon monostachyus (P. Beauv.) Briq.	Labiatae	H	✓	✓	
Spigelia anthelmia L.	Loganaceae	H	✓	✓	✓
Dissotis theifolia (G. Don) Hook. f.	Melastomathaceae	S	✓	✓	
Ficus exasperata Vahl	Moraceae	T		✓	
Peperomia pellucida (L.) H.B. & K.	Piperaceae	H	✓	✓	✓
Panicum maximum Jacq.	Poaceae	G	✓	✓	✓
Trema guineensis (Schum. & Thonn.) Ficalho	Ulmaceae	T	✓	✓	✓
Celtis zenkeri Engl.	Ulmaceae	T	✓	✓	
Laportea aestuans (L.) Chew	Urticaceae	H	✓	✓	✓
Pouzolzia guineensis Benth.	Urticaceae	H	✓	✓	✓
Tectona grandis L. f.	Verbenaceae	T	✓	✓	

Note: C= Climber, G= Grass, H= Herb, S= Shrub, T= Tree.

Table 4. Mean Density (Seeds m^{-2}) and Percentage (%) Contribution of each Species in the Seed Bank of Taungya farm at 0–3 cm, 3–6 cm and 6–9 cm in Akure Forest Reserve.

Name	Family	Habit	0–3 cm	%	3–6 cm	%	6–9 cm	%
Amaranthus viridis L.	Amaranthaceae	H	11	6.67	1	0.719	3	6.667
Xanthosoma mafaffa Schott	Araceae	H	3	1.81	3	2.158	--	--
Chromolaena odorata (L.) R. M. King & H. Rob.	Asteraceae	H	21	12.73	17	12.23	--	--
Cyathula prostrata (L.) Blume	Asteraceae	H	8	4.85	2	1.439	3	6.667
Cnestis ferruginea DC.	Connaraceae	S	4	2.42	1	0.719	--	--
Momordica foetida Schum. & Thonn.	Curcubitaceae	C	8	4.85	6	4.317	3	6.667
Dioscorea preussii Pax	Dioscoreaceae	C	3	1.82	3	2.158	--	--
Euphorbia hirta L.	Euphorbiaceae	H	16	9.70	9	6.475	11	24.44
Phyllanthus capillaris Schum. & Thonn.	Euphorbiaceae	H	12	7.27	17	12.23	--	--
Solenostemon monostachyus (P. Beauv.) Briq.	Lamiaceae	H	6	3.64	7	5.036	--	--
Spigelia anthelmia L.	Loganaceae	H	11	6.67	9	6.475	2	4.444
Dissotis theifolia (G. Don) Hook. f.	Melastomathaceae	S	3	1.82	4	2.878	--	--
Ficus exasperata Vahl	Moraceae	T	--	--	3	2.158	--	--
Peperomia pellucida (L.) H.B. & K.	Piperaceae	H	13	7.88	3	2.158	2	4.444
Panicum maximum Jacq.	Poaceae	G	9	5.46	9	6.475	3	6.667
Trema guineensis (Schum. & Thonn.) Ficalho	Ulmaceae	T	3	1.82	7	5.036	1	2.222
Celtis zenkeri Engl.	Ulmaceae	T	4	2.42	1	0.719	--	--
Laportea aestuans (L.) Chew	Urticaceae	H	14	8.49	13	9.353	2	4.444
Pouzolzia guineensis Benth.	Urticaceae	H	8	4.85	9	6.475	5	11.11
Tectona grandis L. f.	Verbenaceae	T	3	1.82	1	0.719	--	--
Clerodendrum paniculatum L.	Verbenaceae	S	5	3.03	14	10.07	--	--
		Total	**165**	**100**	**139**	**100**	**45**	**100**

Note: C= Climber, G= Grass, H= Herb, S= Shrub, T= Tree.

Seedling emergence at 0–3 cm, 3–6 cm and 6–9 cm depth (Taungya farm) in Akure Forest Reserve, Ondo State

The soil samples collected at 0–3 cm depth showed that a mean total of 165 seeds m^{-2} germinated comprising of 20 species (eleven herbaceous, six woody species and two climbers) belonging to 16 families (Table 4). The herbaceous accounted for 74.6% of all the species identified, the woody species accounted for 13.2%, climber accounted for 6.67% while grass had the least percentage 5.46%. This shows that herbaceous species dominated the soil seed bank of the site at 0-3cm depth. Some of the herbaceous species that emerged were *Amaranthus viridis*, *Cyathula prostrata*, *Chromolaena odorata*, *Euphorbia hirta*, *Peperomia pellucida*, *Laportea aestuans* (L.) Chew, *Pouzolzia guineensis*, *Spigelia anthelmia*, *Solenostemon monostachyus* (P. Beauv.) Briq, *Xanthosoma mafaffa* and *Phyllanthus capillaris.*

A mean total 139 seeds m^{-2} emerged at 3–6 cm depth (Table 4) which constituted 21 species (Eleven herbaceous, seven woody species and two climbers) belonging to 17 families were recorded in the soil seed bank. There were 2 emergences of climbers in this site (6.48%) while grass contributed the least percentage of 6.48%. The herbaceous plant dominated this site by constituting 64.8% of the total species that emerged. It was also noted that of all herbaceous plant here, only *Chromolaena odorata* and *Phyllanthus capillaris* made the highest contribution to the seed bank with a total of 34 seeds m^{-2} (23.5%). The herbaceous species that germinated in this site included; *Amaranthus viridis*, *Chromolaena odorata*, *Euphorbia hirta*, *Peperomia pellucida* and *Laportea aestuans.* The only grass that emerged was *Pouzolzia guineensis* while *Celtis zenkeri* Engl., *Clerodendrum paniculatum* L., *Cnestis ferruginea* DC., *Dissotis theifolia* (G. Don) Hook. f., *Ficus exasperata*, *Trema guineensis* and *Tectona grandis* (22.3%) were the only woody species found here.

At 6–9 cm depth, the mean total 45 seeds m^{-2} which consist only 9 species (seven herbaceous species, one woody species, one climber and one grass) of the families 9 in the above (Table 4). There was one emergence of climber, tree and grass in this site. The herbaceous species dominated the site by constituting 62.22% of all the total species that emerged. These herbaceous were *Amaranthus viridis*, *Cyathula prostrata*, *Euphorbia hirta*, *Laportea aestuans*, *Peperomia pellucida*, *Pouzolzia guineensis* and *Spigelia anthelmia*.

DISCUSSION AND CONCLUSION

In Nigeria, according to Onyekwelu *et al.* (2010), virtually all existing forest plantations, especially those within the tropical rainforests zone, were established on lands that once carried degraded natural forests, when degraded natural forests are converted to forest plantations, the forest landscape changes from multi-species ecosystem to monoculture or at best to 2-species mixed plantation, thus leading to erosion of tree species diversity. Similarities or differences between established vegetation and seed bank give a good estimate of the type of seed bank present and give clues as to the management history of a piece of land and also the life history strategies of plant occupying a particular piece of land (Lopez-Marino *et al*. 2000).

The species richness and diversity of the understorey encountered in this study were 27 (Table 1) which were closely similar to the finding of Onyekwelu *et al.* (2010) who reported in their study that between 10 and 26 different understorey vegetation were encountered in the plantations assessed and this high understorey species richness seems to be characteristics of forest plantations in the tropical rainforest of Nigeria. In similar studies, between 13 and 17 understorey species found abundance in *Gmelina arborea* plantation in the tropical rainforest of Nigeria by Onyekwelu *et al.* (2008). Herbaceous species (Table 1) had the highest number of species (11), trees sapling (2), climbers (5), Shrub sapling (1) and grass (1). This increase in herbaceous species among the understorey could be caused by anthropogenic activities which were mentioned by Gurarni *et al.* (2010) in their result that increased disturbance intensity may favor the invasion of herbaceous species. Decocq *et al*. (2004) reported that species diversity was higher in the disturbed ecosystem than in undisturbed forest. Generally, the results of this finding indicate that species richness and diversity of understorey species in the plantation could encourage biodiversity conservation of indigenous species and consequently, the seedling encountered in this study were all important indigenous and this supported the opinion of Carnus *et al*. (2003) that forest plantation often support a great diversity of native species, particularly in understorey communities and thus can play important role in conserving or even restoring native biodiversity. Studies have shown that plantations can speed the recovery of biodiversity and promote woody species regeneration on re-growth secondary forest lands in tropical regions by speeding up forest succession processes, increase of soil fertility and improving site conditions (Bernhard-Reversat 2001, Cusack & Montagnini 2004, Bajpai *et al.* 2012). Perala & Alban (1982) and Augusto *et al.* (2003) subsequently stated it that understorey vegetation stocks considerable levels of nutrients in the forest, especially during early stages of stand development (Switzer *et al.* 1968).

In this study, the density and composition of soil seed bank were studied and the result showed that density and composition of soil seed banks declined as depth layers increased. Relatively, the comparison studies from other forests (Lemenih & Teketay 2006) showed similar decline in mean density of 912, 278, and 163 m^{-2} of viable seeds in 0–3, 3–6 and 6–9 cm in the Shashamane forest and the species compositions variation also decline along depths. Some species like; *Amaranthus viridis*, *Cyathula prostrata*, *Momordica foetida*, *Euphorbia hirta*, *Spigelia anthelmia*, *Peperomia pellucida*, *Panicum maximum*, *Trema guineensis*, *Laportea aestuans*, *Pouzolzia guineensis* had distribution in all depth layers. Other species, *e.g.*, *Clerodendrum paniculatum*, *Xanthosoma mafaffa*, *Chromolaena odorata*, *Cnestis ferruginea*, *Dioscorea preussii* Pax, *Phyllanthus capillaris*, *Solenostemon monostachyus*, *Dissotis theifolia*, *Celtis zenkeri* , *Tectona grandis* were entirely confined to the first two layers (0–3 and 3–6 cm). Another set of species, *e.g.*, *Ficus exasperata*, etc. were confined to the middle depth layer only. This decrease in soil seeds density was observed by Mamo (2012) who generally reported that there is a decline in the density of soil seed bank flora and a variation in composition along with depth layers. Similarly, at Munessa Shashamane and Menagesha montane forests, Gara Ades (Lemenih & Teketay 2006), the species counts and soil seed bank distribution were observed to be steady with upper soil depth of 3 cm having the highest densities and consequently decreased in densities along increased in soil depth.

The density and diversity indices (Shannon and Simpson) of both the soil seed bank and sapling flora were nearly similar in diversity in this study (Table 2). This result is in agreement with the findings of Poorbabaei & Poorrrahmati (2009), who have reported higher species diversity in the plantations.

Annual wildfire occurrence has always been the reasons behind the poor soil seed density in Akure forest reserve Taungya farm (*Tectona grandis* plantation). The annual wildfire occurrence is mostly set up by the bush hunters to smoke out animals from their hiding which as a result of this lead to a wildfire. This most time favorable only to the buried seed of *Tectona grandis* plantation wildlings. Fire is known to stimulate the germination rate of buried seeds of *Tectona grandis* in Nigeria. In Wondo Genet, Mamo (2012) reported that fire incidence might be one of the reasons behind the low density recorded. Santos *et al.* (2010) recorded that the presence of fire corresponds to lower values of germinated seeds when compared to non-fire modalities, irrespective of depth.

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