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Restoration and Revegetation of Abandoned Ex-Stone Quarry Lands with Tree Species in Southeast Nigeria

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Abstract

A Randomized Complete Block Design with three replicates was used to study the revegetation and restoration of abandoned quarry lands using three tree species (*Adenanthera pavonina*, *Gmelina arborea* and *Acacia auriculiformis*) in Ihube, Okigwe Local Government Area, Imo State, Nigeria. The abandoned stone quarry site chosen measured 45.5m x 45.5m (0.20 ha). The area planted up was 22.5m x 30m. At the site, each of the tree species occupied an area of 7.5m x 30m and was treated as a block. The trees were planted in each block at 2.5m x 2.5m, which gave 12 rows of trees making a total of 36 trees per block and 108 trees of the entire experimental layout. Inorganic fertilizer N.P.K. (20:10:10) treatments were used to enhance tree growth and were applied at the rates of 0, 160, 320, 480 kg/ha. The growth parameters of the tree seedlings investigated were total plant height, stem girth, basal area, canopy cover and canopy sectional area. Data collected were subjected to analysis of variance (ANOVA), and means segregated using Least Significance Difference (LSD). The study showed that *Acacia auriculiformis* had the best plant revegetative attributes of total plant height, canopy cover and canopy sectional area on the abandoned quarry site. The study also showed that *Acacia auriculiformis* had significantly the highest plant height (71.62 cm). *Gmelina arborea* had significantly the highest stem girth (2.62 cm) and stem basal area (3.39 cm^2) in almost all the treatments used. *Acacia auriculiformis* gave significantly the highest canopy cover (386.93 cm^2) and canopy sectional area (3115.40 cm^2). The results obtained from the soil analysis based on the effect of the tree species seedlings on the soil showed that *Adenanthera pavonina* tree seedlings increased the percentage sand content, silt content, base saturation, nitrogen, organic carbon and organic matter. The soil calcium, sodium and ECEC were recorded to have been increased by *Gmelina arborea*. *Acacia auriculiformis* tree seedling increased the soil magnesium while the potassium (K), phosphorus (P), EA and soil pH was not increased by the tree species seedlings. Based on the findings of the study, *Adenanthera pavonina* tree seedling is the best tree species for the reaffoerestation of Ihube abandoned quarry sites and 320 kg/ha inorganic fertilizer application regime is the best level for the establishment of the tree species.

Introduction

The devastation of fertile lands for agricultural purposes due to quarrying processes has led to serious environmental problems, such as soil erosion, water and air pollution the land is abandoned due to its lack in fertility, poor water retention and nutrient leaching. Hence, the need to immediately improve and restore the fertility of the lands for agricultural purposes with trees in addition with inorganic fertilizers is inevitable. Results from the study will hopefully serve as guidelines for proper utilization of ex-stone quarry lands in Southeast Nigeria. The study would not only be useful to Nigeria but also to other African countries that are involved in the stone quarry enterprise.

Mining and mineral processing adversely affects the ecology of the area by disturbing the land mass, the water systems and floral faunal population and in turn the quality of human life. The structure and distribution of trees, shrubs and other ground flora are very sensitive to changes within a short span of time and the major factors influencing these changes are bio-edaphic including two factors that influenced growth performance of species in forestland, which are edaphic factors (soil texture, moisture content, bulk and nutrient content) and climatic factors (Hassan et. al., 2007). These factors exert strong influences on plant development which in turn improve the micro-habitat by regulating the community structure and ecosystem functioning (Soni et. al., 1994).

Stone quarrying activities result in a severe damage to the environment, vegetation and landscape. Revegetation for quarries, especially for quarried faces, however, is always a very thorny thing, and even a world-class difficult problem, which is still resolved unsuccessfully so far. The main reasons resulting in extreme difficulty for revegetation of quarried faces are because:-

1. The surface is very glossy, and there is almost no any soil or loose substrate on it;
2. They are all quite steep, usually up to 70 - 80^{o}, and even perpendicular to the ground; and
3. Most of them are quite high, often up to dozens of meters and even up to over 100m and therefore, are extremely difficult to carry out construction.

Nigeria has abundant stone resources. Stone quarry is therefore one of the most important enterprises in the country. The stone quarry products are used in housing and road constructions. The vigorous quarry operations has left large areas of the land barren and underutilized, while more areas are increasingly coming under stone quarry operations.

The highly devastated, desert-like, ex-stone quarry lands pose serious environmental problems such as soil erosion, water and air pollution. The lands are usually abandoned because they are nutritionally poor as a result of poor water retention capacity and the attendant leaching of nutrients. In view of global concern on environmental restoration and the ever-increasing demand for food, wood and wood products, there is an urgent need to rehabilitate the abandoned ex-stone quarry lands with forest trees and in combination with agricultural crops. The main objective of this research is to evaluate the effectiveness of plant species in the revegetation and restoration of degraded stone quarry site for sustainable land use. Specific Objectives are: (a) to determine the fertilizers and fertilization level for optimal growth of the selected tree species; (b) to evaluate the growth performance of the trees and the revegetative potential of stone quarry site of the three tree species; and (c) to determine the restorative potential of plants (trees) and improvement of soil physical and chemical properties of the site.

MATERIALS AND METHODS

The experiment was conducted at the quarry cite in Amagu, Okigwe, Imo state. Okigwe lies on latitude 7^o 6^1 North and longitude 6^o0^1 East. Okigwe has deep sandy loam soil. The experimental layout was a randomized complete block design (RBC) with six replications. At the site, each of the tree species occupied an area of 42.5m x 42.5m (approximately 0.8 ha) and was treated as a block. The trees were planted in each block at 2.5m x 2.5m, which give 12 rows of trees giving a total of 108 trees per block. The tree species are *Adenanthera pavonina, Gmelina arborea* and *Acacia auriculiformis*.

The trees were raised from seeds during the first two months of the research in the nursery and established on the experimental plots with a spacing of 2.5m x 2.5m at the beginning of the rains. Initial establishment of the trees on the degraded soils was supported by the addition of compost manure or farmyard manure at a radius of 20cm around the seedlings.

Compound NPK fertilizer (20:10:10) were applied. Each treatment was replicated six times, giving a total of 108 seedlings for the three tree species. Fertilizers were applied in solid form in circular trenches (10cm deep x 7.5cm wide) made around the seedlings and 30cm from the base of the seedling.

The following growth attributes were measured at regular intervals; Plant height, Stem girth, Canopy sectional area, Basal area and Canopy cover.

Soil parameters were monitored in the experiment and thoroughly characterized prior to site experimentations in order to assess the degradative conditions of the site. The soil physical and chemical parameters were measured and monitored throughout the experiment.

The data obtained were subjected to analysis of variance (ANOVA) and Least Significant Difference (LSD) was used to separate the means at 5% probability. Correlation and multiple regressions were used to ascertain the relation among soil properties and plant parameters.

RESULT

Growth Assessment

Five growth parameters in each of the three tree species (*Adenanthera pavonina*, *Gmelina arborea* and *Acacia auriculiformis*) for six months were determined. The effects of different N.P.K 20:10:10 fertilizer at 0, 160, 320, and 480 kg/ha applications are shown in Tales 1-5. The growth parameters measured were: plant height (cm), stem girth (cm), basal area (cm^2), canopy cover (cm^2) and canopy sectional area (cm^2).

Plant height (cm)

The effect of different levels of N.P.K (20:10:10) on the tree species height of *Adenanthera pavonina*, *Gmelina arborea* and *Acacia auriculiformis* are shown in Table 1. Analysis of variance showed significant difference effect ($P<0.05$) on the height of the tree species at the termination (6th month) of the experiment.

At the end of the experimental period (6th month), the plant height growth of *Adenanthera Pavonina*, 480 kg/ha recorded the highest tree plant height (75.00 cm), this was followed by 160 kg/ha (70.83 cm), while the control (0 kg/ha) gave the least height growth of 29.17 cm.

In *Gmelina arborea*, the highest height growth (58.33 cm) was recorded by the control at 6th month followed by 160 kg/ha (52.54 cm), while the least was recorded by 320 kg/ha (34.22 cm).

With *Acacia auriculiformis,* the result showed that the control recorded the highest value of 82.52 cm at 6^{th} month followed by 77.17 cm of 160 kg/ha while the least was 320 kg/ha (60.08 cm) recorded at 6th month.

Irrespective of the fertilizer level application, average/cummulative height growths of the tree species at 6th month were 71.62 cm for *Acacia auriculiformis*, 56.68 cm for *Adenanthera pavonina*. and 49.21 cm for *Gmelina arborea*. With these average height growth of the tree species, there is no doubt that the *Acacia auriculiformis* tree species was significantly greater than the height of the *Gmelina arborea* tree species which had the least height growth (Table 1).

Table 1: Effect of different levels of N.P.K. (20:10:10) on the Plant height (cm) of the tree species

Plant Height (cm) Treatment							
	1 month	2 months	3 months	4 months	5 months	6 months	Mean
Adenanthera pavonina							
Control	2.92	7.02	11.67	15.95	23.33	29.17	15.01^{d}
160 NPK per ha	4.94	10.50	31.03	37.83	54.17	70.83	34.88^{a}
320 NPK per ha	5.43	10.38	17.67	35.07	38.33	51.73	26.43^{c}
480 NPK per ha	2.71	10.02	17.00	40.93	50.12	75.00	32.63^{b}
Mean						56.68^{b}	
LSD 0.19							
Gmelina arborea							
Control	3.60	9.85	12.37	25.67	36.67	58.33	24.41^{c}
160 NPK per ha	4.70	13.08	22.50	32.53	42.50	52.54	27.97^{b}
320 NPK per ha	2.89	6.36	9.54	29.79	33.08	34.22	19.31^{d}
480 NPK per ha	3.78	12.42	22.56	34.09	44.53	51.75	28.18^{a}
Mean						49.21^{c}	

LSD 0.16							
Acacia auriculiformis							
Control	4.75	15.85	29.83	45.67	62.50	82.52	40.18[a]
160 NPK per ha	4.67	10.37	25.37	40.35	55.83	77.17	35.62[c]
320 NPK per ha	6.52	5.40	23.39	36.70	47.50	60.08	29.93[d]
480 NPK per ha	10.88	20.00	32.62	41.80	54.17	66.73	37.70[b]
Mean						71.62[a]	
LSD 0.35							

Mean with the same letter within column at the 6th month are not significantly different. LSD= Least significant difference.

Stem girth (cm)

The effect of different levels of N.P.K (20:10:10) on the stem girth of *Adenanthera pavonina, Gmelina arborea*, and *Acacia auriculiformis* tree species is shown in Table 2 below. The effect of different levels of N.P.K (20:10:10) on the stem girth showed significant difference effect ($P<0.05$) on stem girth of the tree species at the termination (6th month) of the experiment.

The stem girth of *Adenanthera pavonina* at the end of the experimental period showed that 480 kg/ha (6 months) gave the largest stem girth of 2.32 cm followed by 160 kg/ha (2.28 cm), while the control (0 kg/ha) recorded the lowest value of 0.87 cm.

In *Gmelina arborea*, the control (0 kg/ha) recorded the largest stem girth 3.38 cm. This was followed by 160 kg/ha with 2.74 cm while the lowest value was 2.17 cm at 480 kg/ha.

In *Acacia auriculiformis*, control (0 kg/ha) recorded the largest stem girth of 2.42 cm followed by 160 kg/ha (1.90 cm). The lowest value was 1.66 cm at 320 kg/ha.

Irrespective of the fertilizer level application, the cumulative average stem girths of the three species at 6th month were 2.62 cm for *Gmelina arborea*, 1.92 cm for *Acacia auriculiformis* and 1.68 cm for *Adenanthera pavonina*. With these average stem girth; *Gmelina arborea* tree species was significantly greater than the stem girth of the *Adenanthera pavonina* tree species, which had the least stem girth.

Table 2: Effect of different levels of N.P.K. (20:10:10) on the Stem girth (cm) of the tree species

Stem girth (mm) Treatment							
	1 month	2 months	3 months	4 months	5 months	6 months	Mean
Adenanthera pavonina							
Control	0.27	0.38	0.52	0.63	0.75	0.87	0.57[d]
160 NPK per ha	0.63	0.97	1.18	1.55	1.92	2.28	1.42[a]
320 NPK per ha	0.50	0.65	0.80	0.96	1.12	1.27	0.88[c]

480 NPK per ha	0.23	0.65	1.07	1.48	1.91	2.32	1.27[b]
Mean						1.68[b]	
LSD 0.09							
Gmelina arborea							
Control	0.45	1.01	1.71	2.27	2.82	3.38	1.94[a]
160 NPK per ha	0.38	0.85	1.32	1.79	2.27	2.74	1.55[b]
320 NPK per ha	0.35	0.72	1.08	1.47	1.83	2.20	1.27[c]
480 NPK per ha	0.30	0.53	0.77	1.03	1.57	2.17	1.06[d]
Mean						2.62[a]	
LSD 0.16							
Acacia auriculiformis							
Control	0.42	0.70	1.08	1.47	1.93	2.42	1.33[a]
160 NPK per ha	0.39	0.65	0.91	1.28	1.53	1.90	1.11[b]
320 NPK per ha	0.35	0.61	0.87	1.13	1.39	1.66	1.00[c]
480 NPK per ha	0.36	0.63	0.90	1.17	1.44	1.72	1.03[c]
Mean						1.92[b]	
LSD 0.12							

Mean with the same letter within column at the 6th month are not significantly different. LSD= Least significant difference.

Basal area (cm^2)

Table 3 below shows the effect of different levels of N.P.K (20:10:10) fertilizer application on the basal area of *Adenanthera pavonina, Gmelina arborea* and *Acacia auriculiformis* tree species. Analysis of variance showed significant difference effect ($P<0.05$) on the basal area of the tree species at the termination (6th month) of the experiment.

In *Adenanthera pavonina*, at the end of the experimental period (6th month), 480 kg/ha recorded the largest basal area value of 2.57 cm^2, followed by 160 kg/ha with basal area of 2.49 cm^2, while the least was the control (0 kg/ha) with the value of 0.36 cm^2.

In *Gmelina arborea,* 0 kg/ha (control) in 6th month, recorded the largest value of 5.45 cm^2, followed by 160 kg/ha with the value of 3.58 cm^2. The least value was 2.24 cm^2 by 480 kg/ha.

In *Acacia auriculiformis*, 0 kg/ha (control) recorded the largest value of 2.79 cm^2, followed by 160 kg/ha with the value of 1.72 cm^2. The least was 320 kg/ha with the value of 1.31 cm^2.

Irrespective of the fertilizer level application, average basal area of the three tree species at 6th month were 3.39 cm^2 for *Gmelina arborea*, 1.81 cm^2 for *Acacia auriculiformis* and 1.54 cm^2 for *Adenanthera pavonina*. With these average basal area of the tree species, *Gmelina arborea* tree species basal area was significantly greater than the basal area of the *Adenanthera pavonina* and *Acacia auriculiformis* tree species.

Table 3: Effect of different levels of N.P.K. (20:10:10) on the Basal area (cm^2) of the tree species

Basal area (cm^2) Treatment							
	1 month	2 months	3 months	4 months	5 months	6 months	Mean
Adenanthera pavonina							
Control	0.03	0.07	0.13	0.19	0.27	0.36	0.17^d
160 NPK per ha	0.19	0.45	0.67	1.15	1.75	2.49	1.11^a
320 NPK per ha	0.12	0.20	0.31	0.44	0.60	0.77	0.40^c
480 NPK per ha	0.03	0.02	0.54	1.05	1.74	2.57	1.02^b
Mean						1.54^b	
LSD 0.03							
Gmelina arborea							
Control	0.10	0.48	1.40	2.45	3.80	5.45	2.28^a
160 NPK per ha	0.07	0.35	0.84	1.54	2.46	3.58	1.47^b
320 NPK per ha	0.06	0.25	0.56	1.03	1.61	2.31	0.97^c
480 NPK per ha	0.04	0.14	0.28	0.51	1.17	2.24	0.73^d
Mean						3.39^a	
LSD 0.09							
Acacia auriculiformis							
Control	0.08	0.23	0.56	1.03	1.79	2.79	1.08^a
160 NPK per ha	0.07	0.20	0.39	0.78	1.12	1.72	0.71^b
320 NPK per ha	0.06	0.18	0.36	0.61	0.93	1.31	0.57^d
480 NPK per ha	0.06	0.19	0.39	0.67	1.00	1.42	0.62^c
Mean						1.81^b	
LSD 0.06							

Mean with the same letter within column at the 6th month are not significantly different. LSD= Least significant difference.

Canopy cover (cm^2)

Table 4 below shows the effect of different levels of N.P.K (20:10:10) fertilizer application on the canopy cover of *Adenanthera pavonina*, *Gmelina arborea* and *Acacia auriculiformis* tree species. Analysis of variance showed significant difference effect ($P<0.05$) on the canopy cover of the tree species at the termination (6th month) of the experiment.

In *Adenanthera pavonina*, 160 kg/ha at the end of the experimental period recorded the highest value of 381.11 cm^2, followed by 480 kg/ha with the value of 283.69 cm^2. The least value was 191.36 cm^2 at 0 kg/ha (control).

In *Gmelina arborea*, 0 kg/ha (control) recorded the highest canopy cover of 272.37 cm^2, followed by 480 kg/ha with the value of 239.90 cm^2. The least was 320 kg/ha with the value of 129.24 cm^2.

In *Acacia auriculiformis*, 320 kg/ha recorded the highest value of 518.59 cm^2, followed by 0 kg/ha with the value of 441.28 cm^2. The least was 160 kg/ha with the value of 275.47 cm^2.

Irrespective of the fertilizer level application, average canopy cover of the three tree species at 6th month were 386.93 cm^2 for *Acacia auriculiformis*, 267.69 cm^2 for *Adenanthera pavonina* and 195.20 cm^2 for *Gmelina arborea*. With these average canopy cover of the tree species, *Acacia auriculiformis* tree species canopy cover was significantly greater than the canopy cover of the *Gmelina arborea* tree species.

Table 4: Effect of different levels of N.P.K. (20:10:10) on the Canopy cover (cm^2) of the tree species

Canopy cover (cm^2) Treatment							
	1 month	2 months	3 months	4 months	5 months	6 months	Mean
Adenanthera pavonina							
Control	5.89	19.96	41.37	167.83	187.35	191.36	102.29^d
160 NPK per ha	4.52	7.01	80.40	104.22	328.32	381.11	150.93^a
320 NPK per ha	7.69	28.85	93.85	149.68	182.15	214.61	112.80^b
480 NPK per ha	6.59	23.55	60.83	109.23	142.37	283.69	104.37^c
Mean						267.69^b	
LSD 1.20							
Gmelina arborea							
Control	5.64	9.52	21.94	135.46	185.48	272.37	105.06^b
160 NPK per ha	19.95	23.37	93.89	97.92	132.48	139.32	84.48^c
320 NPK per ha	6.29	67.35	76.51	82.45	96.36	129.24	76.36^d
480 NPK per ha	13.10	55.37	106.96	112.53	170.89	239.90	116.45^d
Mean						195.20^c	
LSD 1.02							
Acacia auriculiformis							
Control	9.43	15.80	19.73	76.51	345.10	441.28	151.30^c
160 NPK per ha	10.71	16.10	135.57	158.78	222.28	275.47	136.48^d

320 NPK per ha	34.76	88.11	219.72	259.60	340.04	518.59	243.47[a]
480 NPK per ha	53.88	101.49	106.83	212.65	263.58	312.39	175.13[b]
Mean						386.93[a]	
LSD 2.06							

Mean with the same letter within column at the 6th month are not significantly different. LSD= Least significant difference.

Canopy sectional area (cm²)

Table 5 below shows the effect of different levels of N.P.K (20:10:10) fertilizer application on the canopy sectional area of *Adenanthera pavonina, Gmelina arborea,* and *Acacia auriculiformis* tree species. Analysis of variance showed significant difference effect ($P<0.05$) on the canopy sectional area of the tree species at the termination (6th month) of the experiment.

In *Adenanthera pavonina*, at the end of the experimental period (6th month), 160 kg/ha recorded the highest canopy sectional area of 4901.82 cm². This was followed by 480 kg/ha with canopy sectional area of 4360.35 cm², while the control (0 kg/ha) recorded the least value of 360.83 cm². The canopy sectional area of *Gmelina arborea* at the end of the experimental period, 0 kg/ha (control) recorded the highest value of 4432.32 cm². This was followed by 160 kg/ha with the value of 2848.25 cm², while the least was 320 kg/ha canopy sectional area of 1335.48 cm².

In *Acacia auriculiformis*, 0 kg/ha (control) gave the highest canopy sectional area of 5773.43 cm². This was followed by 480 kg/ha with canopy sectional area of 2658.43 cm². The lowest value was recorded by 320 kg/ha with canopy sectional area of 1731.37 cm².

Irrespective of the fertilizer level application, average canopy sectional area of the three tree species at 6th month were 3115.40 cm² for *Acacia auriculiformis*, 2728.61 cm² for *Gmelina arborea* and 2615.21 cm² for *Adenanthera pavonina*. With these average canopy sectional areas of the tree species, there is no doubt that the *Acacia auriculiformis* tree species canopy sectional area was significantly greater than the canopy sectional area of the *Gmelina arborea* and *Adenanthera pavonina*.

Table 5: Effect of different levels of N.P.K. (20:10:10) on the Canopy Sectional area (cm²) of the tree species

Canopy Sectional area (cm²) Treatment							
	1 month	2 months	3 months	4 months	5 months	6 months	Mean
Adenanthera pavonina							
Control	1.18	8.38	31.45	220.07	301.63	360.83	153.92[d]
160 NPK per ha	5.20	18.85	417.92	553.12	4009.32	4901.82	1651.03[a]

320 NPK per ha	5.53	247.73	327.30	471.30	766.15	837.87	442.64[c]
480 NPK per ha	1.10	13.10	21.47	688.13	1484.88	4360.35	1094.83[b]
Mean						2615.21[c]	
LSD 1.70							
Gmelina arborea							
Control	3.27	27.50	184.10	4009.32	4230.87	4432.32	2147.89[a]
160 NPK per ha	8.38	48.83	471.30	1283.12	1443.35	2848.25	1017.20[b]
320 NPK per ha	2.20	99.00	277.02	471.30	1244.53	1335.48	571.58[d]
480 NPK per ha	3.41	44.85	189.05	327.30	1686.50	2298.40	758.25[c]
Mean						2728.61[b]	
LSD 2.08							
Acacia auriculiformis							
Control	4.72	22.13	66.28	471.30	4726.10	5773.43	1843.99[a]
160 NPK per ha	4.71	19.49	374.72	940.61	1853.92	2298.40	915.31[b]
320 NPK per ha	11.82	92.52	500.35	1120.15	1443.35	1731.37	816.59[d]
480 NPK per ha	19.94	121.79	236.47	837.83	1584.10	2658.43	909.76[c]
Mean						3115.40[a]	
LSD 2.45							

Mean with the same letter within column at the 6th month are not significantly different. LSD= Least significant difference.

Soil Analysis

Soil Physical Properties

Figure 1. below shows the effect of *Adenanthera pavonina* L. , *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth on the soil physical properties after 24 weeks (6 months) period. The analysis of variance showed no significant effect ($P<0.05$) of the tree species seedlings on the soil physical properties.

Adenanthera pavonina gave the highest value of 61.97 % for the percentage sand content of the soil above that of the control (60.63 %), this was followed by *Gmelina arborea* with 61.63 %.
The percentage silt content was highest with *Adenanthera pavonina* with value of 8.50 % as compared to control with 7.17 % silt content.
Acacia auriculiformis increased the percentage clay content with 33.2 % value while the control value was 32.20 %.

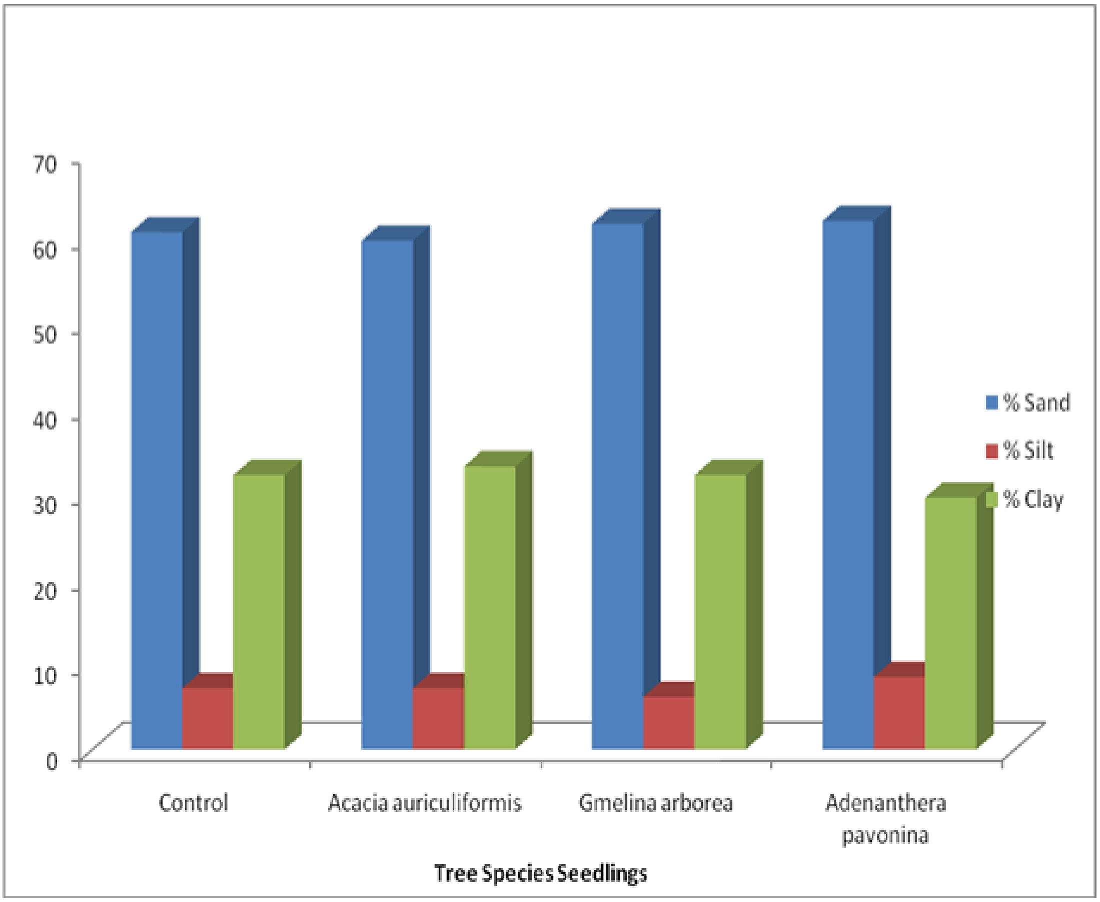

Figure 1: Effect of *Adenanthera pavonina* L, *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on the soil physical properties.

Soil Chemical Properties

Soil pH, Exchangeable acid, Effective CEC and percentage Base Saturation.
The effect of *Adenanthera pavonina* L. *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex. Benth tree seedlings on the chemical properties of the soil is shown in figure 2. below. The analysis of variance showed no significant effect ($P<0.05$) of the trees on the soil chemical properties.
The soil pH and Exchangeable acid was not increased by the tree species seedlings. The effective CEC value was increased by *Gmelina arborea* with 9.31 value; this was followed by *Adenanthera pavonina* with 8.92 ECEC value. The percentage base saturation value was increased by *Adenanthera pavonina* with 85.09 % as compared to the control value of 78.88 %.

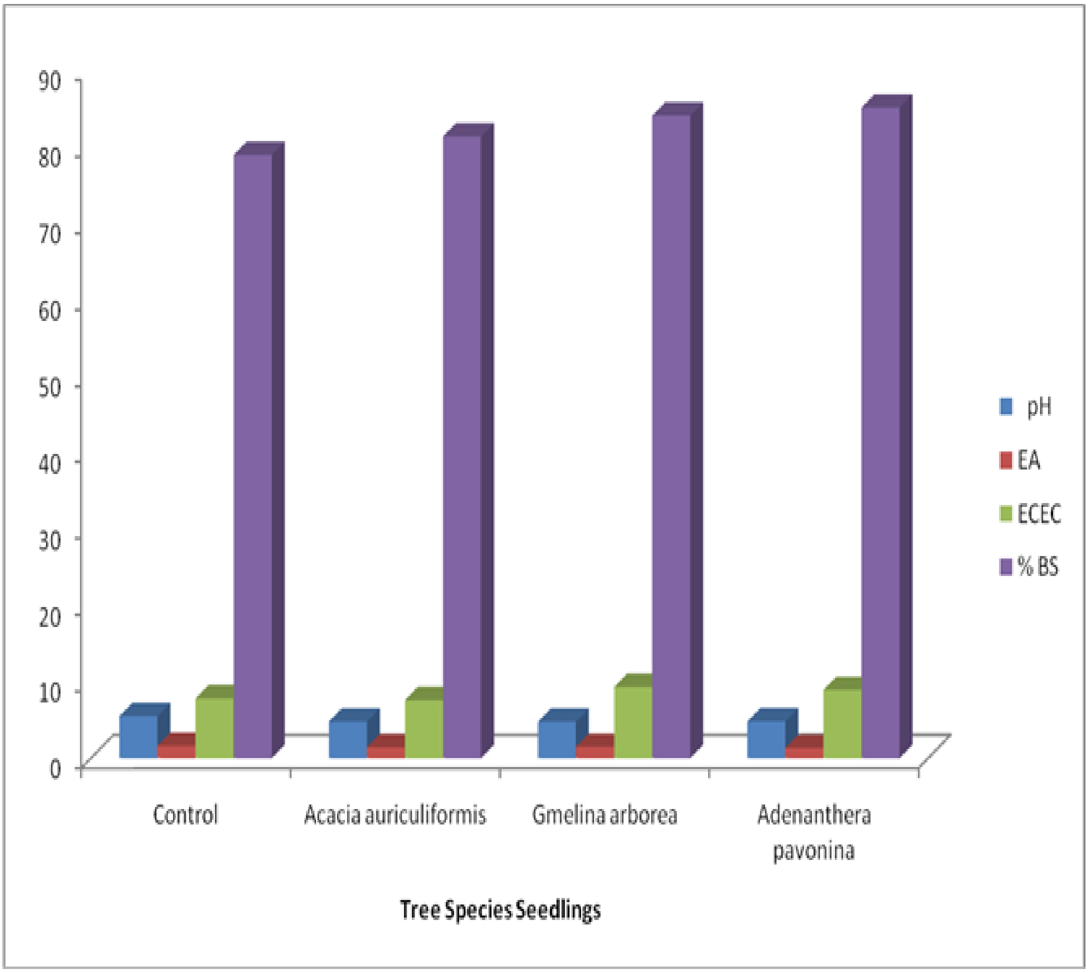

Figure 2: Effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on the soil pH, Exchangeable acid, Effective CEC and percentage Base Saturation.

Percentage Soil Nitrogen, Phosphorus and Potassium.

The effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth on the percentage nitrogen, phosphorus and potassium of the soil is shown in figure 3. below. Analysis of variance showed no significant effect ($P < 0.05$) of the tree species seedlings on the nitrogen, phosphorus and potassium content of the soil.

The soil nitrogen was improved greatly by *Adenanthera pavonina* with nitrogen percentage value of 0.12 % followed by *Acacia auriculiformis* (0.09 %). *Gmelina arborea* gave the least soil nitrogen with 0.08%.

The percentage phosphorus level of the soil was not improved by the tree species seedlings of *Adenanthera pavonina* (32.03 %), *Gmelina arborea* (30.03 %), and *Acacia auriculiformis* (28.90 %) while control was 32.40 %.

The percentage potassium level of the soil was not increased by the tree species seedlings of *Adenanthera pavonina* (0.23 %), *Gmelina arborea* (0.17 %), and *Acacia auriculiformis* (0.23 %) while control was 0.26 %.

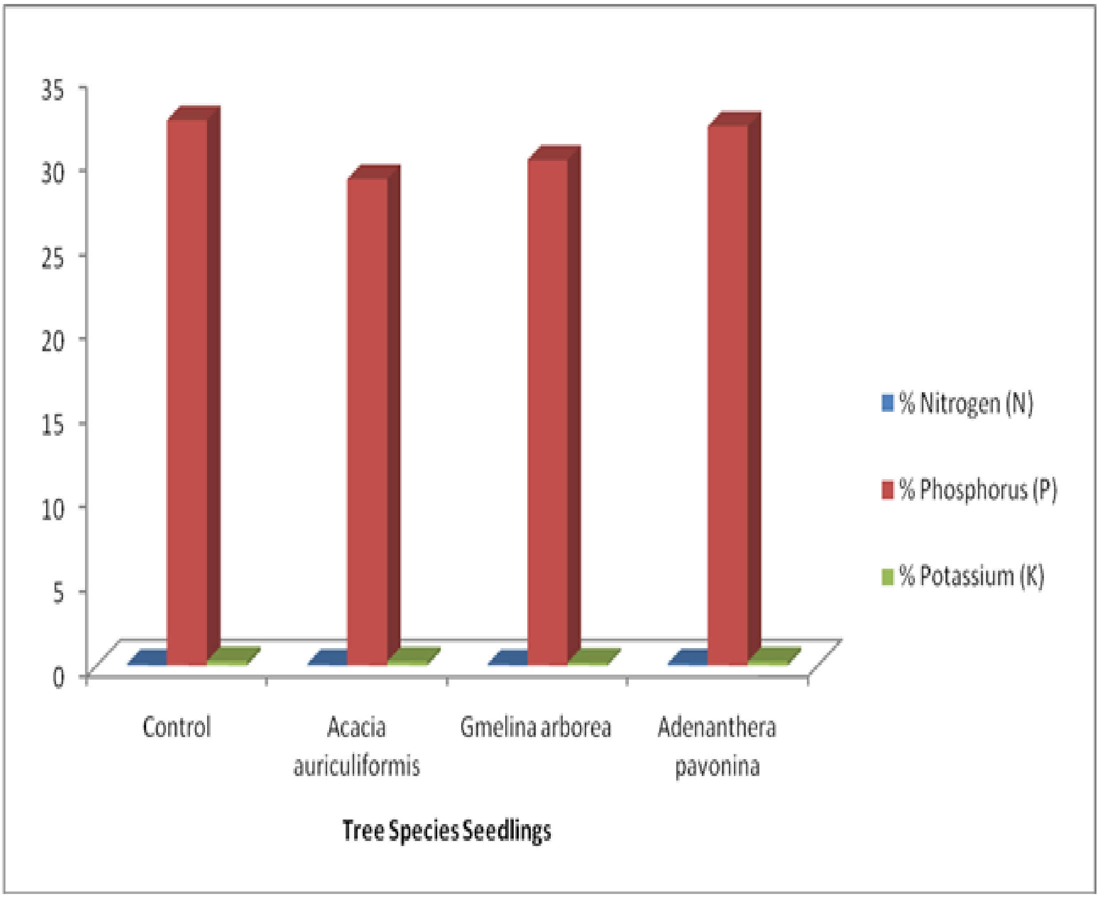

Figure 3: Effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on the soil nitrogen (N), Phosphorus (P) and Potassium (K).

Percentage Sodium (Na), Calcium (Ca) and Magnesium (Mg).

Figure 4. below shows the effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth on the sodium(Na), Calcium (Ca) and Magnesium (Mg) content of the soil after 24 weeks (6 months) period. Analysis of variance showed no significance ($p<0.05$) in the soil after 24 weeks.

Percentage sodium (Na) was highest with *Gmelina arborea* with value of 0.17 %; this was followed by *Acacia auriculiformis* 0.15 %. *Adenanthera pavonina* recorded the least value (0.14%) for percentage sodium (Na).

Percentage Calcium (Ca) was highest with *Gmelina arborea* with value of 6.13 %; this was followed by *Adenanthera pavonina* with 5.73 % while *Acacia auriculiformis* recorded the least value (4.67 %) for percentage calcium (Ca). Analysis of variance showed no level of significance ($P <0.05$) between the tree species seedlings and the percentage calcium content of the soil.

Acacia auriculiformis recorded the highest value (1.47 %) for percentage magnesium, this was followed by the control with 1.20 % while *Adenanthera pavonina* L. recorded the lowest value of 0.80 % for magnesium.

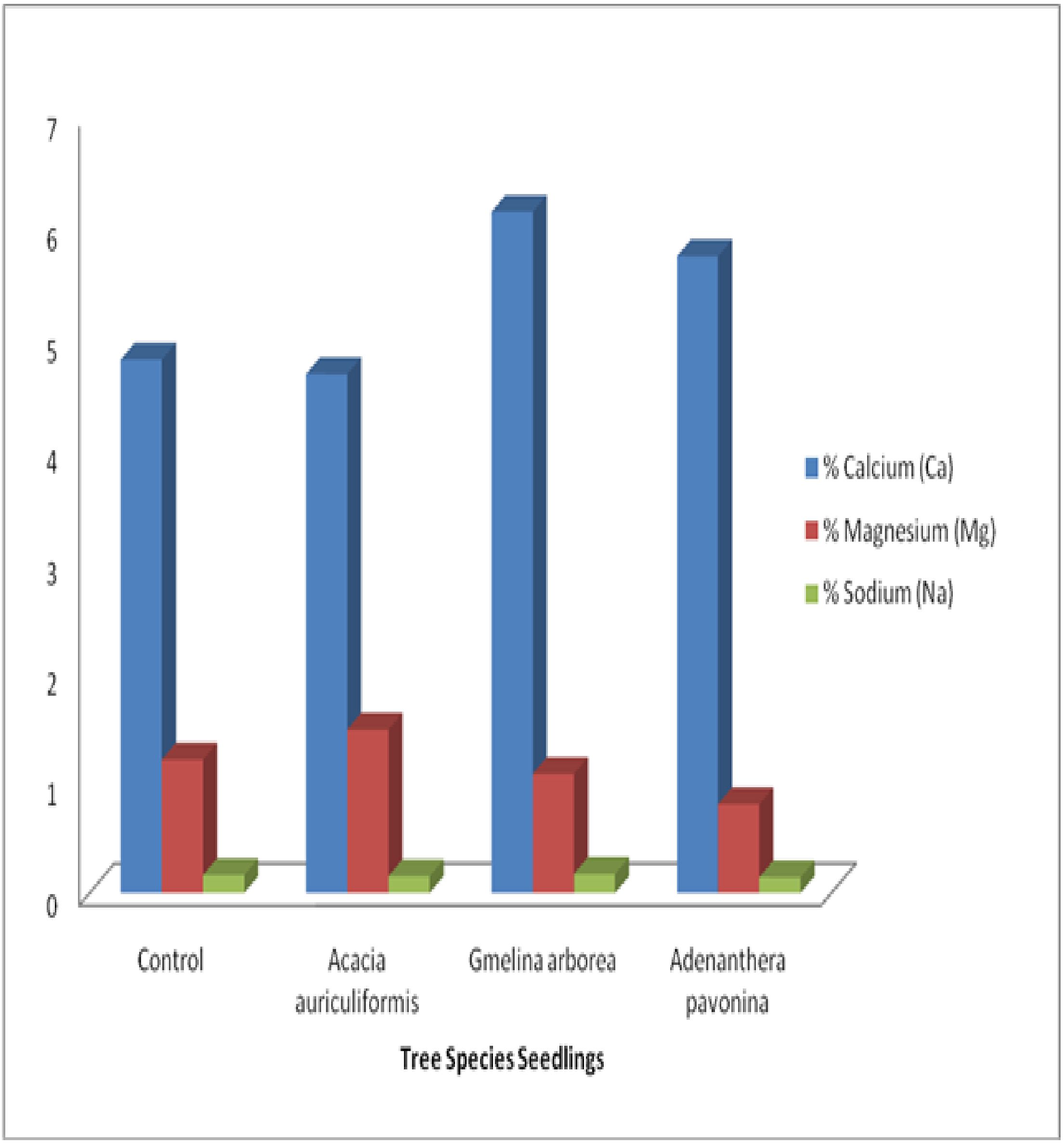

Figure 4: Effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on soil sodium (Na), Calcium (Ca) and Magnesium (Mg).

Percentage Organic Carbon

Figure 5. shows the effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth on the percentage organic carbon content of the soil after 24 weeks (6 months) period.

The tree species seedlings showed no significant effect ($P < 0.05$) on the percentage organic carbon of the soil. Adenanthera pavonina recorded the highest level of soil organic carbon content with value of 1.41 %, followed by the control with 1.1 %. The least soil organic carbon content was recorded with *Gmelina arborea* with value of 0.95 %.

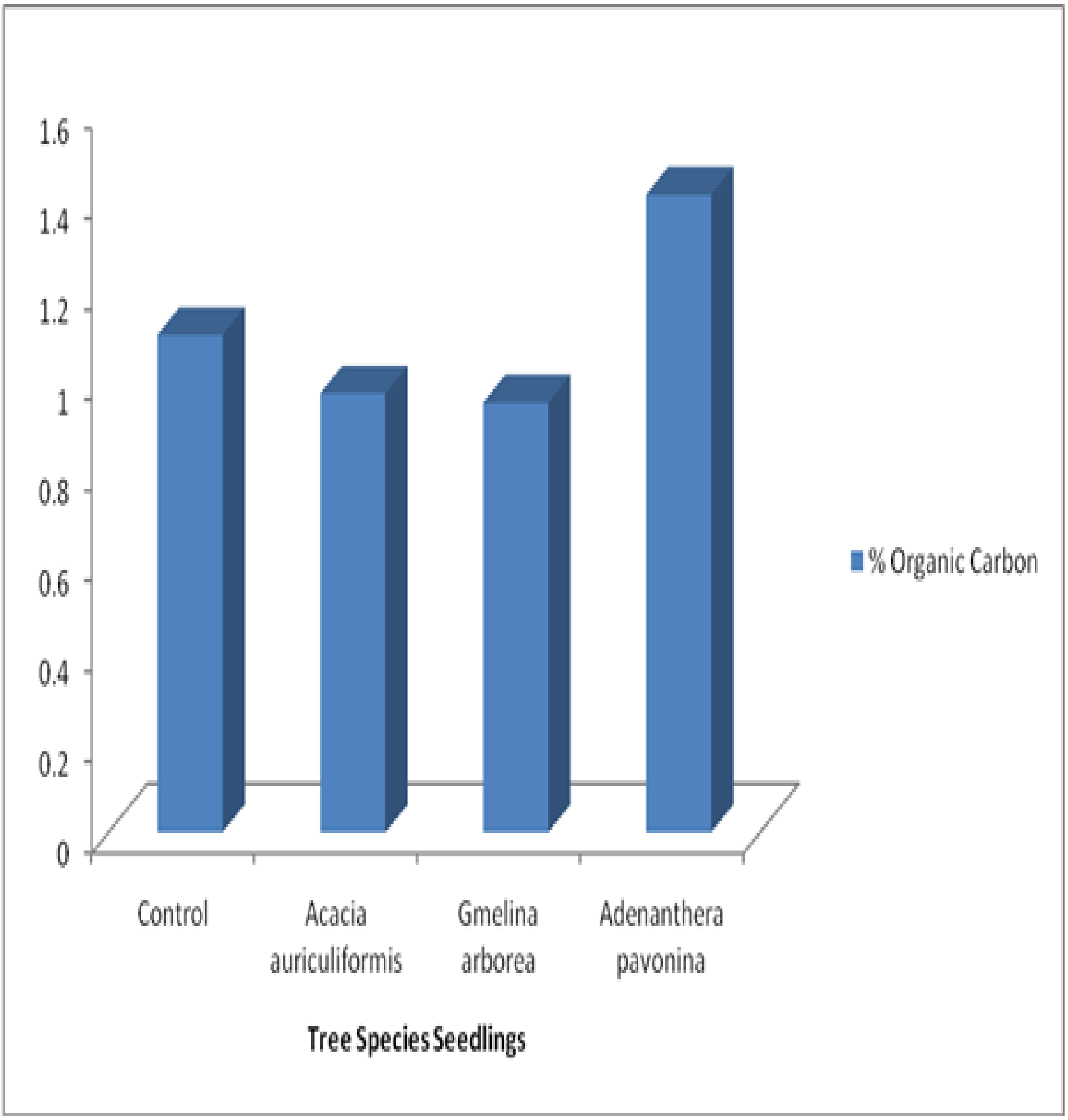

Figure 5: Effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on soil organic carbon.

Soil Organic Matter (SOM).

Figure 6. shows the effect of *Acacia auriculiformis* A. Cunn. ex Benth, *Gmelina arborea* Roxb., and *Adenanthera pavonina* L. on the percentage organic carbon content of the soil after 24 weeks (6 months) period. The tree species seedlings showed no significant effect on the soil organic matter content of the soil after 24 weeks (6 months).

The organic matter content was recorded highest in *Adenanthera pavonina* (2.44 %), this was followed by the control with 1.89 % in organic matter while *Gmelina arborea* recorded the least with 1.64 % organic matter.

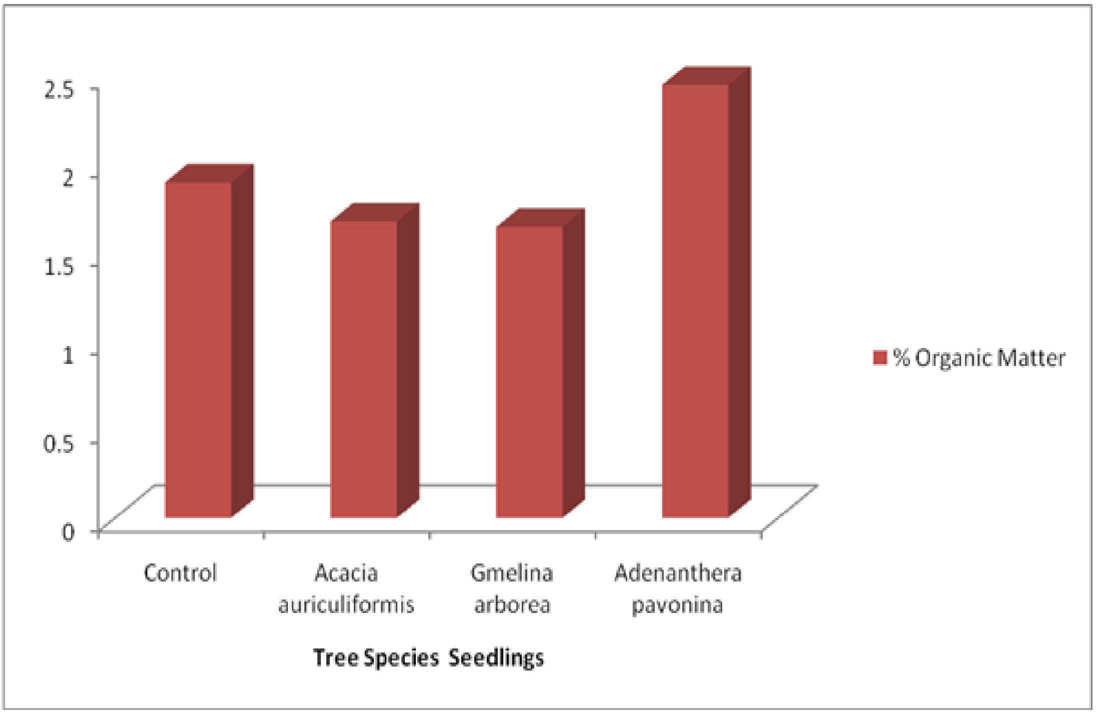

Figure 6: Effect of *Adenanthera pavonina* L., *Gmelina arborea* Roxb., and *Acacia auriculiformis* A. Cunn. ex Benth tree species seedlings on soil organic matter.

DISCUSSION

The study showed that *Acacia auriculiformis* had significantly the highest plant height in all the treatments used. Trees are always considered in restoring degraded mine sites. This is in line with the findings of Assel (2006); Kohnke and Bertrand (1989). They reported that trees have been found to improve soil fertility. Young (1989) also observed in forestry reclamation, the afforestation of eroded or otherwise degraded land has demonstrated the power of trees to build up soil fertility. Negri (2003); Pulford and Watson (2003); Coates (2005); Padmavathiamma and Li (2007); Mertens *et al.*, (2007) reported that trees can potentially improve soils through numerous processes, such as increase water infiltration and storage, uptake of nutrients from below and reduce loss of nutrients by erosion and leaching. Ingram (1999) reported that severed processes have been identified by which trees can enhance the chemical and physical properties of the soils. Troech *et al.,* (1980) also pointed out that the establishment of the vegetation on soils disturbed by constructional activities, and the subsequent increase in soil organic matter on these soils, result in the improvement of soil hydrophysical and chemical properties.

Gmelina arborea had the highest stem girth and stem basal area in this study. *Gmelina arborea* tree species usually attain moderate to a large height up to 30m with the girth of 1.2 to 4 (Singh et al., 2004; Singh and Singh, 2006). They also stated that *Gmelina arborea* does not thrive on ill-drained soils and remains stunted on dry, sandy or poor soils (ex-stone quarry site). This may be responsible for the least height growth of *Gmelina arborea* tree species recorded at the 6th month. However, *Gmelina arborea* attained significantly the highest mean stem girth and basal area at the end of the experiment.

Acacia auriculiformis had the highest mean tree canopy cover and canopy sectional area in all the treatments used. All these indicate that the tree species will provide the needed hydrological protection of the land through the interception of rainfall by foliage thereby reducing surface runoff (Nwaigbo, 2019). Consequently, from the study carried out by Aggrawal (1980) and cited by Young (1989) showed the possible effects of vegetation establishment (revegetation) on soil properties under the canopy of individual trees and those in the surrounding areas without tree cover.

Trees improve or maintain soil fertility and productivity, promote soil conservation, reduce soil degradation and achieve sustainable production (Noble and Randell, 1998). The tree species seedlings showed no significant effect ($P < 0.05$) on the soil physical properties after 24 week period of the study. This is not surprising given the short period of the study. The sand content was increased by *Adenanthera pavonina* (61.97 %) and *Gmelina arborea* (61.63 %) as against 60.63 % for the control. *Adenanthera pavonina* and *Acacia auriculiformis* (8.50 % and 7.17 %) increased the soil silt content while the clay content was maintained by *Gmelina arborea* and *Acacia auriculiformis* tree seedlings. This agreed with the work of Adje (2016) where he opined that trees improve the structure of the soil and reduce soil compaction.

In this study, the establishment of the tree seedlings with soil fertilization decreased the soil pH and electrical conductivity as compared to the control soil. These are in conformity with Noble (1998) who stated that the establishment of trees cause a significant decrease in soil pH and soil electrical conductivity. However, the tree seedlings increased the percentage (%) Base saturation of 81.30 %, 84.03 % and 85.09 % for *Acacia auriculiformis*, *Gmelina arborea* and *Adenanthera pavonina* respectively as against 78.88% for the control.

There was no significant effect ($P < 0.05$) of the tree species seedlings due to N.P.K. fertilization on the Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na) and Phosphorus (P) content of the soil. This could be attributed to the use of these nutrients by the tree seedlings for growth since they are very much available in the soil. However, *Gmelina arborea* increased the Calcium (Ca) and Sodium (Na) content of the soil. This is in agreement with the findings of Swamy *et al*., (2004) who reported a significant improvement in soil nutrient status under *Gmelina arborea* plantation in Nigeria and India.

Adenanthera pavonina and *Acacia auriculiformis* tree seedlings in this study are able to maintain the soil nitrogen despite the depletion of nutrients through uptake by the plants by addition of nitrogen through fixation. This study agreed with the findings of Imoro *et al*., (2013) which recorded that planting of leguminous trees have been shown to contribute nutrients to the soil through nitrogen fixing and through recycling of residues which also contribute organic matter into the soil.

The soil organic carbon (OC) and soil organic matter (SOM) are increased by *Adenanthera pavonina* tree seedlings followed by *Acacia auriculiformis* tree seedlings. Soil organic matter acts as a source of nitrogen, phosphorus, sulphur and cations. It has a direct influence in increasing the Cation Exchange Capacity (CEC) of a soil (Imoro *et al.,* 2013).

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