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ASSESSMENT OF PLANT SPECIES FOR REVEGETATION OF ABANDONED QUARRY SITE IN SOUTHEAST NIGERIA

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ABSTRACT

A randomized complete block design with six replicates was used to assess plant species for revegetation of abandoned quarry site in Southeast Nigeria using leguminous cover crops and fertilizer applications. Tree species used were Adenanthera pavonina, Gmelina arborea, and Acacia auriculiformis. The leguminous cover crops were Mucuna utilis, Stylosanthes gracilis and Centrosema pavonina and fertilizer applications were 100 NPK, 200 NPK and 300 NPK. Acacia auriculiformis had significantly the highest plant height, canopy sectional area and canopy cover irrespective of fertilizer application and leguminous cover crops. Gmelina arborea had significantly the highest stem girth and basal area irrespective of the fertilizer applications and leguminous cover crops. Adenanthera pavonina had the least result of the above parameters. In plant height, the best fertilizer application and leguminous cover crops for Acacia auriculiformis were 300 NPK and Stylosanthes gracilis respectively. For Gmelina arborea, 100 NPK and Stylosanthes gracilis were the best fertilizer application and leguminous cover crop respectively. In terms of canopy sectional area, Acacia auriculiformis and Gmelina arborea gave significantly the highest and the least respectively, irrespective of the fertilizer application and leguminous cover crops. In terms of canopy cover, Acacia auriculiformis had significantly the highest. 300 NPK fertilizer applications in Acacia auriculiformis gave significantly the highest canopy cover, followed by Stylosanthes gracilis and Centrosema pubescens. The least was Gmelina arborea both in fertilizer application and leguminous cover crops. Adenanthera pavonina was the least in all the parameters except in canopy sectional area and canopy cover irrespective of the fertilizer applications and leguminous cover crops. There is a significant difference between the plant height and stem girth, canopy sectional area, basal area, canopy cover, and Potassium. Increase in plant height significantly increase stem girth, canopy sectional area, basal area, canopy cover, and potassium. There is a significant difference between the stem girth and canopy sectional area (CSA), basal area (BA), canopy cover (CC), and Potassium (K). Increase in stem girth significantly increases the CSA, BA, CC and K. This study recommends the use of A. auriculiformis trees for rehabilitating and restoring quarried sites

KEYWORDS: *Assessment, Plant Species, Revegetation, Quarry Site*

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INTRODUCTION

Engineering effect of quarrying is most obvious on the environment. Mining or quarrying distorts nature by disturbing unique habitats, significant alteration of topography and unchecked disruption of basic ecological relationships (Walker and Del Moral, 2003; Sharma and Roy, 1997). Walker and Del Moral 2003 reported that land is a critical resource for people dependent on farming. They also noted that about 2 million hectares of agricultural lands are lost every year due to anthropogenic activities which affect the ecosystem and cause severe land degradation. Townsend *et al*. 2008; Ata-Era, 2016; Tischew *et al*. 2014; Akanwa *et al.* 2016 noted that quarrying activities have altered vegetation cover worldwide such as the Appalachian Mountains, Netherlands, Ghana, Germany, and Nigeria. Mining and quarrying activities are destructive enterprises. Akanwa *et al.* (2016) reported that undergrowth clearance is perhaps the prime cause of environmental dilapidation and exhaustion of natural communities worldwide.

Excavation sceneries are visually dramatic as pronounced by Ukpong (2012). The sentiments were nearly comparable to David's, (2007) who termed open quarry pits in Hungary as "scars in the landscape. Ukpong (2012) mentioned that the state of the topography is a creation of the unwarranted excavation of the earth surface and disregard of the natural sceneries. An observation was made by Ukpong (2012) in Akampka, Nigeria, that bounteous smaller excavations upset the environment to a greater degree as opposed to one large excavation, meaning that environmentally conscious artisanal miners have an opportunity of amalgamating their operations and capitalizing on deep excavations rather than scattering so as to minimize ecological upsets including the earth's geomorphology.

Nawaz *et al*. (2004) recounted a manifestation of such occurrences where they used remote sensing technique to demonstrate how Margatta hills in Pakistan were at the brink of being vanished by stone miners at the western side. Zelalem (2016) in Ethiopia, found that although stone mining was a lucrative business in semi-urban zones of Addis Ababa, it concerned environmentalists that it irreversibly exhausted natural resources, a fact resounded by Haule *et al*. (2016) whose study in Mbeya region of Tanzania revealed that limestone mining caused extensive losses of soil and vegetation covers. Therefore, this study was conducted with the following objectives (a) to determine the best fertilization regimes for optimal growth of the selected tree species (b) to determine the best leguminous cover crops for the growth of the tree species and soil conservation (c) to determine the growth performance of the trees and the best tree species in rehabilitating the land.

MATERIALS AND METHODS

This experiment was conducted at the quarry site in Ihube, Okigwe LGA, Imo State, Nigeria. Okigwe lies on latitude 7^0 6^1 North and longitude 6^0 0^1 East. Okigwe has deep sandy loam soil with the following physiochemical properties: (a) *Adenanthera pavonina's* plot (% sand 61.8, % silt 10.80, % clay 27.40, TEX sandy clay, pH 6.2, EA 0.56, ECEC 7.70, % BS 92.73); (b) *Gmelina arborea's* plot (% sand 65.8, % silt 8.80, % clay 25.40, TEX sandy clay, pH 5.9, EA 1.36, ECEC 14.83, %BS 90.36) and (c) *Acacia auriculiformis'* plot (% sand 63.80, % silt 9.80, % clay 26.40, TEX sandy clay, pH 6.05, EA 0.96, ECEC 11.27, %BS 9.55).

The experimental layout was a randomized complete block design (RBC) with six replicates. 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 gives 12 rows of trees making a total of 72 trees per block and 216 trees for the entire experimental layout. The data obtained were subjected to analysis of variance and Duncan's New Multiple

Range (ANOVA) and Least Significant Difference (LSD) was used to separate the means at 5% probability level. Correlation and Multiple regressions were used to ascertain the relationship between soil properties and plant parameters. The tree species are (a) *Adenanthera pavonina* (b) *Gmelina arborea* and (c) *Acacia auriculiformis*. The trees were established on the experimental plots with a spacing of 2.5m x 2.5m at the beginning of the rains. The 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 (14-14-14) was applied. Each treatment was replicated six times, giving a total of 72 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 application was repeated every year. The tree species were grown under the following cover crops as possible substitutes to inorganic fertilization and control of weed growth. The leguminous cover crops used were: (a) *Mucuna utilis* (b) *Centrosema pubescens* and (c) *Stylosanthis gracilis.* The experiment was a two-factor factorial (3 x 3), made up of 3 tree species and 3 cover crops. The following growth attributes were measured at regular intervals until the trees reach their economic age: (a) Plant height (b) Stem girth (c) Canopy sectional area (d) Basal area and (e) Canopy Cover.

Soil Studies and Characterization

All the soil parameters monitored in the experiment was thoroughly characterized prior to site experimentations in order to assess the degradative conditions of the site. The following soil parameters were measured and monitored throughout the experiment.

Soil Physical Properties

The following physical properties were monitored: Dry bulk density(BD) (Core method), Textural class (TEX), Total porosity (TP) and pore-size distribution (pF determination using undisturbed core samples and disturbed core samples), Infiltration rate (double ring infithometer method), Moisture retention characterization (pF determination), Unsaturated hydraulic conductivity (instantaneous profile method by gravimetric and tensiometric measurements, Soil moisture content (MO) and suction profile (gravimetric and tensiometric methods).

Soil Chemical Properties

Soil pH, organic Carbon (OC), organic matter (OM), total Nitrogen content (TN), available Phosphorus (AVP), calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Aluminum (Al), total exchangeable acidity, Effective Cation Exchange Capacity (ECEC), percentage base saturation (%BS) were monitored during site characterization and subsequently during the experiment. These soil parameters were monitored at 5cm depth increments to a depth of 50cm. soil samples were collected from adjacent grids on which the soil physical properties were measured. Sampling was at intervals of two months and was staggered to coincide with monitoring of soil physical properties.

RESULTS

Growth

A total of five growth parameters in each of the three tree species (*Adenanthora pavonina* L., *Gmelina arborea* Roxb. and *Acacia auriculiformis* A. Cunn. ex-Benth) for six months (Table 1:- August 2018 to January 2019) were examined in this study. The effects of different leguminous crops (*Mucuna utilis*, *Stylosanthis gracilis* and *Centrosema pubescens*) and fertilizer (100, 200 and 300 NPK) applications grown in the field for the six months are presented in table 1. The growth parameters measured were: plant height, stem girth, canopy sectional area, basal area and canopy cover.

Table 1: Effects of Leguminous Cover Crops and Fertilization Applications on Growth Performance of the 3 Tree Species in August 2018 – January 2019

		Adenanthora Pavonina L.					Gmelina Arborea Roxb.					Acacia Auriculiformis A. Cunn. Ex. Benth				
TRT	Month	PIH(cm)	SG(cm)	CSAr	BA	CC	PIH(cm)	SG(cm)	CSAr	BA	CC	PIH(cm)	SG(cm)	CSAr	BA	CC
Mucuna	August 2018	17.5	1.6	7.07	0.2	35.35	21.6	2.1	19.64	0.35	56.11	28.5	2.5	28.3	0.5	56.6
Mucuna	September 2018	33	2.4	31.18	0.46	67.78	36	3.1	19.64	0.76	25.84	37	1.8	66.48	0.26	255.69
Mucuna	October 2018	34	2.62	31.18	0.55	56.7	38.5	3.3	38.5	0.87	44.25	60	2.8	113.11	0.62	182.44
Mucuna	November 2018	38	1.9	38.5	0.29	132.76	45	2.5	95.05	0.5	190.1	67	5.8	122.73	2.68	45.79
Mucuna	December 2018	39	2.1	38.5	0.35	110	54.3	5.58	113.11	2.48	45.61	71	6	143.16	2.86	50.06
Mucuna	January 2019	42.1	3.1	50.3	0.76	66.18	59.1	5.2	165	2.15	76.74	73	6.5	132.75	3.36	39.51
Mean		33.93	2.29	32.79	0.44	78.13	42.42	3.63	75.16	1.19	73.11	56.08	4.23	101.09	1.71	105.02
Stylosa	August 2018	14.5	1.2	4.91	0.11	44.64	32.5	3.9	66.48	1.21	54.94	50.5	2.2	95.91	0.39	245.92
Stylosa	September 2018	26.5	1.5	28.28	0.18	157.11	48.5	4.22	96.78	1.42	68.15	76	3.7	154	1.09	141.28
Stylosa	October 2018	33.5	2.3	31.18	0.42	74.24	51	4.98	103.88	1.97	52.75	83	4	245.5	1.27	193.31
Stylosa	November 2018	34	2.1	28.28	0.35	80.8	62	7.2	176.74	4.12	42.9	84	4.3	283.57	1.47	192.9
Stylosa	December 2018	46	2.9	52.5	0.67	78.36	76.8	10.61	283.57	8.96	31.65	85	6.44	314.2	3.3	95.21
Stylosa	January 2019	52	3.3	63.6	0.87	73.1	78.1	10.1	292.59	8.12	36.03	87	6.8	346.41	3.68	94.13
Mean		34.42	2.22	34.79	0.43	84.71	58.15	6.84	170.01	4.30	47.74	77.58	4.57	239.93	1.87	160.46
Centros	August 2018	23	1.9	15.91	0.29	54.86	25.7	2.5	22.91	0.5	45.82	48.2	2	86.6	0.32	270.63
Centros	September 2018	28.5	3.5	29.23	0.97	30.13	30	2.3	63.63	0.42	151.5	52	2.4	98.53	0.46	214.2
Centros	October 2018	32	2	33.19	0.32	103.72	39.5	3.2	84	0.81	103.7	55	2.8	102.08	0.62	164.85
Centros	November 2018	36	2.8	19.64	0.62	31.68	47	4.8	96.4	1.83	52.68	57	3.7	112.08	1.09	102.83
Centros	December 2018	42	2.03	50.28	0.33	152.36	57	8.12	132.75	5.25	25.29	59	3.42	111.23	0.93	119.6
Centros	January 2019	48	3.6	54.2	1.03	52.62	60	8.6	154	5.88	26.19	60.2	4.1	115.01	1.34	85.83
Mean		34.92	2.64	33.74	0.59	70.90	43.20	4.92	92.28	2.45	67.53	55.23	3.07	104.26	0.79	159.66
Fert-100	August 2018	29.15	3.8	31.18	1.15	27.11	28.2	2.7	50.27	0.58	86.67	28	2.35	28.28	0.44	64.27
Fert-100	September 2018	30	1.6	33.19	0.2	166	52	6.15	103.9	3.01	34.52	34	2.7	50.27	0.58	86.67
Fert-100	October 2018	31	2.7	28.28	0.58	48.76	59.5	7.92	165.15	5	33.03	42.3	2.3	80.13	0.42	190.79
Fert-100	November 2018	39	2.8	50.27	0.62	81.08	72	8.2	254.5	5.35	47.57	50	4.2	95.05	1.4	67.89
Fert-100	December 2018	60	3.54	78.55	1	78.55	74	10	257.34	7.96	32.32	59	4.33	111.23	1.49	74.65
Fert-100	January 2019	63	3.81	113.11	1.16	97.51	78.5	10.27	293	8.39	34.92	62.2	5.1	116.91	2.07	56.48
Mean		42.03	3.04	55.76	0.79	83.17	60.70	7.54	187.36	5.05	44.84	45.92	3.50	80.31	1.07	90.13
Fert-200	August 2018	32.5	3.9	33.2	1.21	27.44	17.35	1.8	13.2	0.26	50.77	39	2.8	70.89	0.62	114.34
Table 1 Contd.,																
Fert-100	September 2018	30	1.6	33.19	0.2	166	52	6.15	103.9	3.01	34.52	34	2.7	50.27	0.58	86.67
Fert-100	October 2018	31	2.7	28.28	0.58	48.76	59.5	7.92	165.15	5	33.03	42.3	2.3	80.13	0.42	190.79
Fert-100	November 2018	39	2.8	50.27	0.62	81.08	72	8.2	254.5	5.35	47.57	50	4.2	95.05	1.4	67.89
Fert-100	December 2018	60	3.54	78.55	1	78.55	74	10	257.34	7.96	32.32	59	4.33	111.23	1.49	74.65
Fert-100	January 2019	63	3.81	113.11	1.16	97.51	78.5	10.27	293	8.39	34.92	62.2	5.1	116.91	2.07	56.48
Mean		42.03	3.04	55.76	0.79	83.17	60.70	7.54	187.36	5.05	44.84	45.92	3.50	80.31	1.07	90.13
Fert-200	August 2018	32.5	3.9	33.2	1.21	27.44	17.35	1.8	13.2	0.26	50.77	39	2.8	70.89	0.62	114.34
Fert-200	September 2018	38	3.5	38.5	0.97	39.69	28	1.8	50.27	0.26	193.35	51	2.5	96.78	0.5	193.56
Fert-200	October 2018	40	4.2	50.27	1.4	35.91	38	5	83.33	2	41.67	53.5	3.8	100.3	1.15	87.22
Fert-200	November 2018	41.8	2.25	51	0.4	127.5	42	5.6	95.05	2.5	38.02	55	3.9	102.08	1.21	84.36
Fert-200	December 2018	42	3.3	50.3	0.87	57.82	44	6.11	95	2.97	31.99	94	6.32	572.63	3.18	180.07
Fert-200	January 2019	43.1	3.8	50.57	1.15	44	50	6.6	105.88	3.47	29.94	98	7.1	706.95	4.01	176.3
Mean		39.57	3.49	45.64	1.00	55.39	36.56	4.49	73.79	1.91	64.29	65.08	4.40	274.94	1.78	139.31
Fert-300	August2018	16.27	1.4	6.61	0.61	41.31	22.7	2.3	20.43	4.21	4.85	65.3	3.57	119.61	1.01	118.43
Fert-300	September 2018	21.5	1.6	15.9	0.2	79.5	38	3.51	83.33	0.98	85.03	77	2.6	176.74	0.54	327.3
Fert-300	October 2018	40.5	4.2	51.54	1.4	36.81	44.5	4.1	95.04	1.34	70.93	81.5	2.6	201.09	0.54	372.39
Fert-300	November 2018	52	3.1	63.63	0.76	83.7	56.5	5.3	132.75	2.24	59.26	87	4.3	346.41	1.47	235.65
Fert-300	December 2018	57	3.21	56.75	0.82	69.21	71	8.6	254	5.88	43.2	97	6.81	660.61	3.69	179.03
Fert-300	January 2019	60.1	3.9	78.6	1.21	65	74.5	10.15	269.1	8.2	32.82	99.1	7.1	730.71	4.01	182.22
Mean		41.23	2.90	45.51	0.83	62.59	51.20	5.66	142.44	3.81	49.35	84.48	4.50	372.53	1.88	235.84
LSD(0.05)A=trt		2.68	0.2	4.88	0.08	8.35	4	0.65	20.01	0.63	9.38	4.44	0.37	41.81	0.27	18.25
LSD(0.05) B=Month		2.68	0.2	4.88	0.08	8.35	4	0.65	20.01	0.63	9.38	4.44	0.37	41.81	0.27	18.25
LSD(0.05) C=trt X Month		6.56	0.48	11.94	0.21	20.44	9.79	1.58	49.02	1.54	22.99	10.87	0.9	102.4	0.66	44.71

Key: plH= Plant Height, SG= Stem Girth, CS = Canopy Sectional Area, BA= Basal Area, CC= Canopy Cover, LSD=least significant difference, A= treatment, B=month,C=interaction between A and B, *= significant, ns=not significant. *Adenanthera pavonina* L.

Plant Height

Figure 1 summarizes the effects of leguminous cover crops and fertilizer applications on plant height and growth performance of the three tree species used in revegetating and rehabilitating the ex-stone quarry site. For the tree species – *A. pavonina* L., the leguminous cover crop *Mucuna utilis* had the mean growth of 33.93cm. *Stylosanthis gracilis* had 34.42cm. *Centrosema pubescens* had 34.92cm. In the fertilizer application of the tree species A. pavonina L., the mean 100 NPK application was 42.03cm. Mean 200 and 300 NPK application was 39.57cm and 41.23cm respectively. At the end of the growth period, 100 NPK attained the highest average height of 42.03cm while *Mucuna utilis* had the least 33.93cm.

There is a significant difference in the treatments used (legume and fertilizer application) over time. At the end of the growth period of *A. pavonina* L., 100 NPK attained significantly the highest plant height of 42.03cm followed by 300 NPK with plant height 41.23cm. *Mucuna utilis* had the least ($P \leq 0.05$) plant height over time. There is a significant difference among the location (lower, middle and upper) in months of plant height of *A. pavonina* L. where 100 NPK in the month of January 2019 had 63.00cm. However, in terms of treatment and location interactions over time, the 63.00cm recorded at 100 NPK in January 2019 was significantly highest irrespective of treatment and location.

Gmelina Arborea Roxb

For *G. arborea* Roxb, *M. utilis* attained an average plant height of 42.40cm. *S. gracilis* had a mean height of 58.15ccm. *C. pubescens* had average plant heights of 43.20cm. For fertilizer application, 100 NPK had an average height of 60.70cm. 200 NPK had average plant heights of 36.56cm. Lastly, 300 NPK had a mean height of 51.20cm.

At the end of the growth period, for *G. arborea* Roxb, 100 NPK had the highest mean of 60.70cm while 200 NPK had the least mean height of 36.56cm.

There is a significant difference among the treatments over time. At the end of the growth period for *G.arborea* Roxb, 100 NPk attained significantly ($P \leq 0.05$) the highest plant height of 60.70cm. 200 NPK had the least ($P \leq 0.05$) plant height of 36.56cm over time when compared with the control (*Mucuna utilis*) having an average mean of 42.42cm. Again there is a significant difference among location (lower, middle and upper position on the sloppy site). In months of plant height of *G. arborea* Roxb., 100 NPK in January at the end of the growth period had the highest plant height of 78.50cm followed by *S. gracilis* in January 2019 having 78.10cm while the least was 200 NPK having the plant height of 17.35cm in September 2018. However in terms of treatment and location interactions over time; in January 2019, the highest plant height of 78.50cm recorded by 100 NPK was significant irrespective of the treatment and location.

Acacia Auriculiformis

M. utilis attained mean plant height of 56.08cm. *S. gracilis* had a mean height of 77.58cm. *C. pubescens* had an average plant height of 55.23cm. 100 NPK attained average plant heights of 45.92cm. 200 NPK had 65.08cm while 300 NPK had an average height of 84.48cm.

There is a significant difference among the treatment over time. At the end of the growth period for *A. auriculiformis*, 300 NPK attained significantly the highest plant height of 84.48cm while 100 NPK had the least ($P \leq 005$)

plant height of 45.92cm over time. There is also a significant difference among location. In months of plant height of *A. auriculiformis,* 300 NPK in January 2019 had the highest plant height of 99.10cm while the least was 100 NPK in August 2018 with a plant height of 28.00cm. However, in terms of treatment and location interactions over time, 300 NPK having the highest plant height of 99.10cm was significant irrespective of the treatment and location.

In summary, the study revealed that the plant height of *A. auriculiformis* was the highest in almost all the treatments used. The least in plant height was *A. pavonina*. The study also revealed that 300 NPK fertilizer applications were the best for optimal growth in plant height of *A. auriculiformis*. Among the leguminous cover crop applications, *S. gracilis* was the best for *A. auriculiformis* production in plant height.

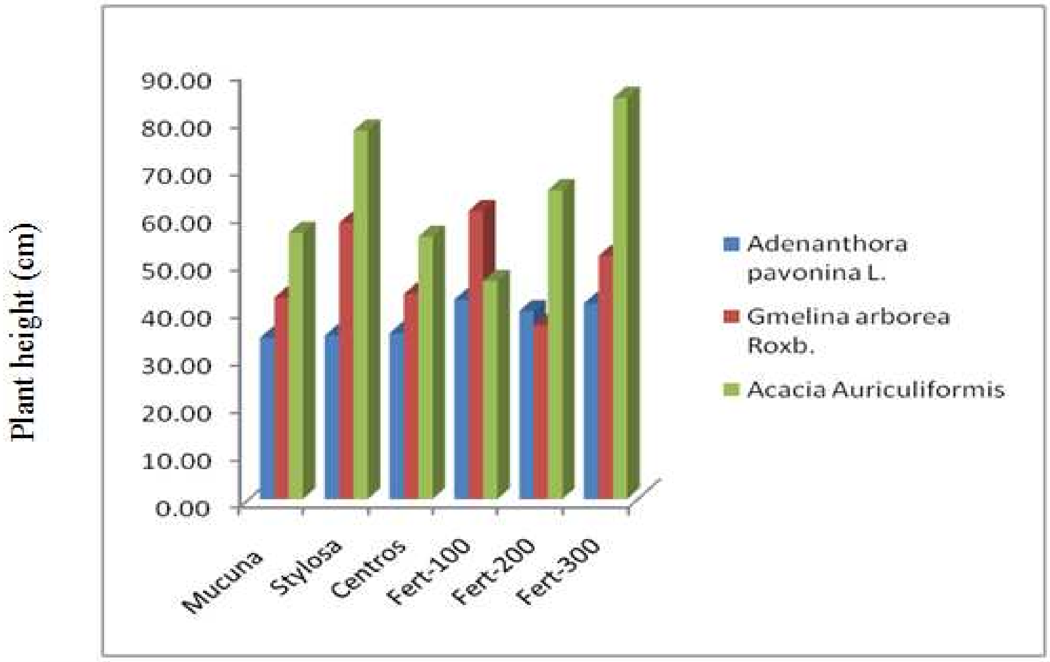

Figure 1: Leguminous Cover Crops and Fertilizer Applications on Plant Height (Cm)

Stem Girth

Figure 2 shows the effects of different leguminous cover crops and fertilizer applications on stem girth growth performance of the three tree species used in the study in the ex-stone quarry site.

Adenanthera Pavonina

For *A. pavonina* L. leguminous cover crop *M. utilis* (as the control) attained a mean growth of 2.29cm. *S. gracilis* had 2.22cm, while *C. pubescens* had 2.64cm. In fertilizer application, 100 NPK attained a mean growth of 3.04cm. 200 NPK attained a mean growth of 3.49cm. 300 NPK attained mean growth of 2.90cm. At the end of the growth period 200 NPK had the highest mean stem girth of 3.49cm when compared to the control (*M. utilis* 2.29).

There is a significant difference among the treatments used over time. At the end of the growth period, 200 NPK attained significantly the highest stem girth of 3.49cm followed by 100 NPK of stem girth 3.04cm. *S. gracilis* had the least ($P \leq 0.05$) stem girth over time. There is a significant difference among location (lower, middle and upper) in the month of stem girth. At the end of the growth period, both 200 and 300 NPK attained stem girth of 4.2cm each in October 2018. However, in terms of treatment and location interactions over time, there is a significant difference in that 200 and 300

NPK attained the highest stem girth of 4.2cm each irrespective of the treatment and location when compared to the control (*M. utilis* 2.29).

Gmelina Arborea Roxb

In *G. arborea* Roxb., *M. utilis* attained mean stem girth of 3.630cm. *S. gracilis* had an average mean of 6.84cm *C. pubescens* had mean stem girth of 4.92cm. 100 NPK had attained the average mean of 7.54cm. 200 NPK had an average mean of 4.49cm. 300 NPK attained an average mean of 5.66cm. At the end of the growth period, 100 NPK had the highest stem girth of 7.54cm and the least ($P \leq 0.05$) was *M. utilis* with 3.63cm.

There is a significant difference among the treatments used over time. At the end of the growth period, 100 NPK had significantly the highest mean stem girth of 7.54m. *M. utilis* had the least ($P \leq 005$) mean stem girth of 3.63cm (control). There is a significant difference among locations in months of stem girth of *G. arborea* where *S. gracilis* had the highest stem girth of 10.61cm in December 2018 and the least being 200 NPK with 1.80cm stem girth in August and September 2018. However, there is also a significant difference among interactions between treatments and locations over time. *S. gracilis* recorded the highest stem girth of 10.61cm in December 2018 at the end of the experiment irrespective of treatment and location.

Acacia Auriculiformis

In *A. auriculiformis*, *M. utilis* attained mean stem girth of 4.23cm. *S. gracilis* had mean stem girth of 4.57cm. *C. pubescens* had mean stem girth of 3.07cm. 100 NPK attained average stem girth of 3.50cm. 200 NPK attained mean stem girth of 4.40cm. 300 NPK had mean stem girth of 4.50cm. At the end of the growth period, *S. gracilis* had the highest mean stem girth of 4.57cm.

There is a significant difference among the treatments over time. At the end of the growth period, *S.gracilis* had significantly the highest mean stem girth of 4.57cm. *C. pubescens* had the least ($P \leq 0.05$) mean stem girth of 3.07cm over time when compared with the control (*M. utilis* 4.23). There is a significant difference among location in months of the stem girth. At the end of the growth period, 200 and 300 NPK had the highest stem girth of 7.10cm each in January 2019. However, in terms of treatment and location interactions over time, 7.10cm recorded by 200 and 300 NPK in January 2019 was significantly highest irrespective of treatment and location.

In summary, the study revealed that *G. arborea* had the highest stem girth in almost all the treatments used. The least was *A. pavonina*. *G. arborea* sown under 100 NPK recorded the highest mean stem girth at the end of the treatments. Among the leguminous cover crop, *S. gracilis* was the best for *G. arborea* production of stem girth.

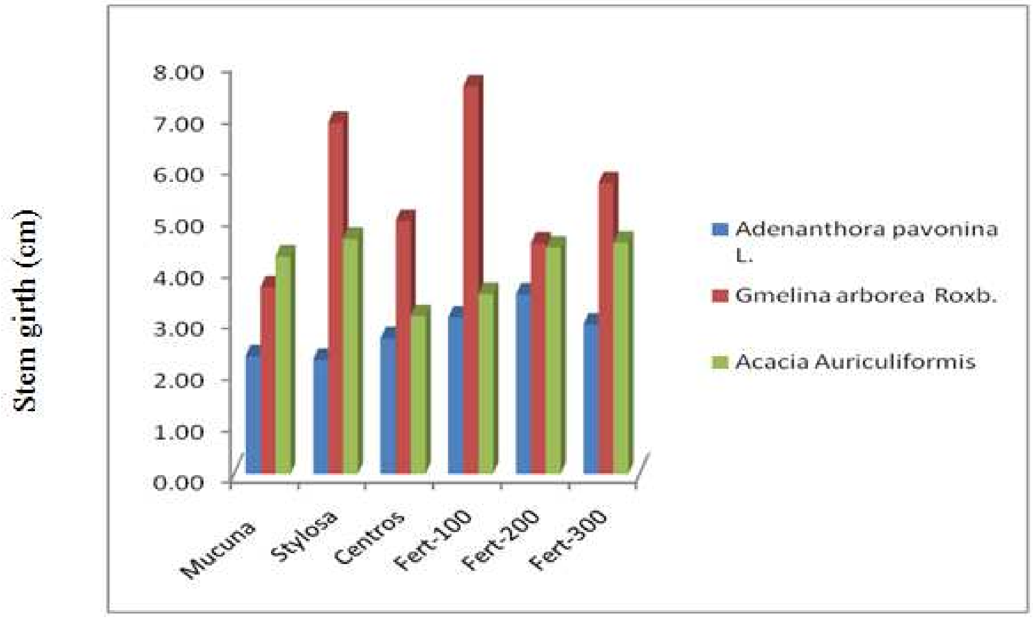

Figure 2: Leguminous Cover Crops and Fertilizer Applications on Stem Girth (Cm)

Canopy Sectional Area

Figure 3 shows the effects of different leguminous cover crop and fertilization application on canopy sectional area on growth performance of the tree species used in the study in the ex-stone quarry site.

Adenanthera Pavonina

Here *M. utilis* had average canopy sectional area (CSA) of 32.79. *S. gracilis* had mean CSA of 34.79. *C. pubescens* mean CSA of 33.74. 100 NPK attained average CSA of 55.76. 200 NPK attained average CSA of 45.64 and 300 NPK had 45.51. At the end of the growth period, 100 NPK fertilizer application had the highest mean CSA of 55.76, and the least being *M. utilis* with 32.79 CSA.

There is a significant difference among the treatment over time. At the end of the growth period, 100 NPK application had significantly the highest mean CSA of 55.76. *M. utilis* had the least mean ($P \leq 0.05$) CSA of 32.79 over time. There is a significant difference among location in months of the CSA. At the end of the growth period, 100 NPK had the highest CSA of 113.11 in January 2019. However, in terms of treatment and location, there is a significant difference. 113.11 recorded by 100 NPK in January 2019 were significantly highest irrespective of treatment and location.

Gmelina Arborea

For *G. arborea*, *M. utilis* attained mean CSA of 75.16. *S. gracilis* had mean CSA of 170.01. *C. pubescens* had CSA of 92.28. For fertilizer application of 100 NPK, the mean CSA was 187.36. 200 NPK attained an average mean of 73.79. 300 NPK attained mean of 142.44. At the end of the growth period, 100 NPK had the highest mean CSA of 187.36 when compared with the control (*M. utilis*).

There is a significant difference among the treatment over time. At the end of the growth period, 100 NPK fertilizer applications had significantly the highest mean CSA of 187.36. 200 NPK had the least mean ($P \leq 0.05$) CSA of 73.79 over time. There is a significant difference among location in months of the CSA. At the end of the growth period, 100 NPK had the highest CSA of 293 in the month of January in 2019. However, in terms of treatment and location interactions over time, there is a significant difference; 100 NPK recorded the highest CSA of 293 at the end of the experiment irrespective of treatment and location.

Acacia Auriculiformis

M. utilis attained mean CSA of 101.09. *S. gracilis* had 239.93. *C. pubescens* attained mean CSA of 104.26. For fertilizer application, 100 NPK attained mean CSA of 80.31. 200 NPK had 274.94, while 300 NPK had mean CSA of 372.53. At the end of the growth period, *A. auriculiformis* grown under 300 NPK had the highest mean CSA of 372.53 when compared with the control (101.09) and the least being 100 NPK with CSA of 80.31.

There is a significant difference among the treatment over time. At the end of the growth period, 300 NPK had significantly the highest mean CSA of 372.53 over time. There is a significant difference among location in months of the CSA. At the end of the growth period, 300 NPK had the highest CSA of 730.71 in January 2019. There is also a significant difference among interactions between treatments and locations over time. 300 NPK recorded the highest CSA of 730.71 in January 2019 at the end of the study irrespective of treatment and location**.**

In summary, the study revealed that *A. auriculiformis* had the highest mean canopy sectional area in all the treatments used. The least was *G. arborea*. The study also revealed that 300 NPK was the best fertilizer application for optimal canopy sectional area of *A. auriculiformis*. Among the leguminous cover crops, *S. gracilis* and *C. pubescens* was the best for canopy sectional area.

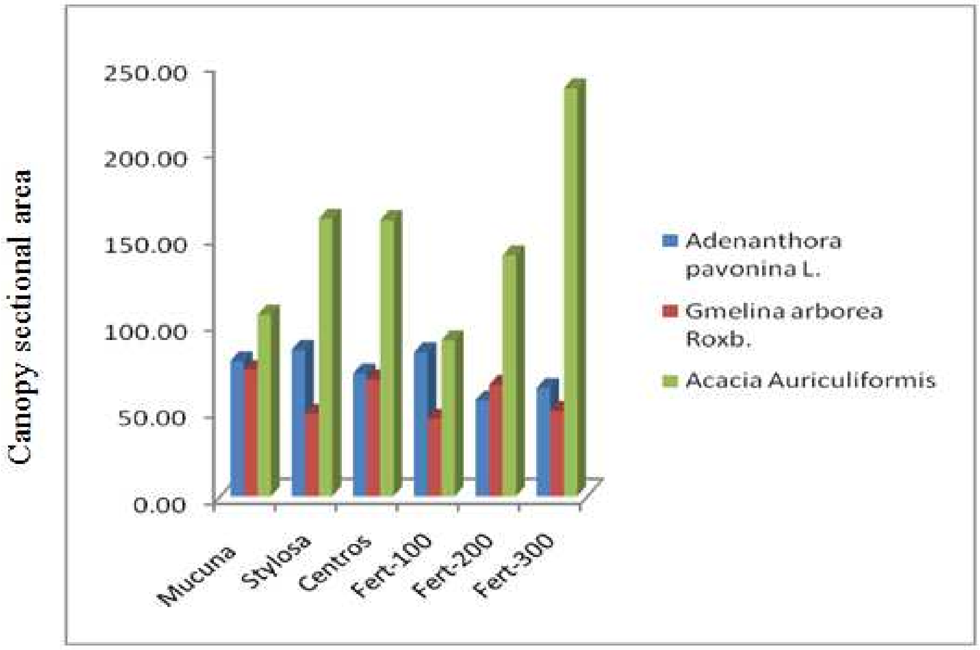

Figure 3: Leguminous Cover Crops and Fertilizer Applications on Canopy Sectional Area (CSA)

Basal Area

Figure 4 shows the effects of different leguminous cover crops and fertilizer applications on basal area growth performance of the three tree species used for the study in the ex-stone quarry site.

Adenanthera Pavonina

Here, *M. utilis* attained mean basal area 0.44. *S gracilis* had 0.43. *C. pubescens* had a mean basal area of 0.53. In fertilizer application, 100 NPK attained mean basal area of 0.79. 200 NPK attained 1.00, while 300 NPK had a mean basal area of 0.83. At the end of the growth period, 200 NPK had the highest mean basal area of 1.00 when compared with the control (*M. utilis* with 0.44 basal area).

There is a significant difference among the treatments over time. At the end of the growth period, 200 NPK had significantly the highest basal area of 1.00 over time. *S. gracilis* had the least ($P \leq 0.05$) basal area of 0.43. There is a significant difference among location in months of the basal area. At the end of the growth period, 300 NPK had the highest basal area of 1.21 in January 2019. However, in term of treatment and location interactions over time, there is a significant difference, 300 NPK had the highest basal area of 1.21 in January 2019 at the end of the experiment irrespective of treatment and location.

Gmelina Arborea

M. utilis attained mean basal area of 1.19. *S. gracilis* attained mean basal area of 4.30. *C. pubescens* had 2.45. 100 NPK had a mean basal area of 5.05. 200 NPK attained mean basal area of 1.91, while 300 NPK attained mean basal areas of 3.81. At the end of the growth period, 100 NPK had the highest mean basal area of 5.05. The least ($P \leq 0.05$) basal area of 1.19 was recorded by *M. utilis* and 200 NPK when compared with the control.

There is a significant difference among the treatments over time. At the end of the growth period, 100 NPK had significantly the highest basal area of 5.05. There is a significant difference among locations in months of the basal area of *G. arborea* where *S. gracilis* had the highest basal area of 8.96 in December 2018. There is also a significant difference among interactions between treatments and locations over time. *S. gracilis* recorded the highest basal area of 8.96 in December 2018 at the end of the experiment irrespective of treatment and location.

Acacia Auriculiformis

Here, *M. utilis* attained mean basal areas of 1.71. *S. gracilis* attained mean basal areas of 1.87. *C. pubescens* had 0.79. In fertilizer application, 100 NPK had attained a mean basal area of 1.07. 200 NPK had 1.78 while 300 NPK attained 1.88. At the end of the growth period, 300 NPK had the highest mean basal area of 1.88 while the least ($P \leq 0.05$) was *C. pubescens* with 0.79 basal area when compared with the control (*M. utilis* 1.71).

There is a significant difference among the treatments over time. At the end of the growth period, 300 NPK had significantly the highest mean basal area of 1.88 and the least ($P \leq 0.05$) was *C. pubescens* with 0.79 when compared with the control (*M. utilis*). There is a significant difference among locations in months of the basal area. At the end of the growth period, 200 and 300 NPK had the highest basal area of 4.01 each in January 2019. However, there is a significant difference in terms of interactions among the treatment and location over time. 200 and 300 NPK in January 2019 recorded the highest basal areas of 4.01each irrespective of treatment and location.

In summary, the study revealed that *G. arborea* had the highest mean basal area in almost all the treatments used. The least was *A. pavonina*. The study also revealed that 100 NPK was the best fertilizer application for the optimal basal area for *G. arborea*. Among the leguminous cover crop, the study revealed that *S. gracilis* was the best for basal area production of *G. arborea.*

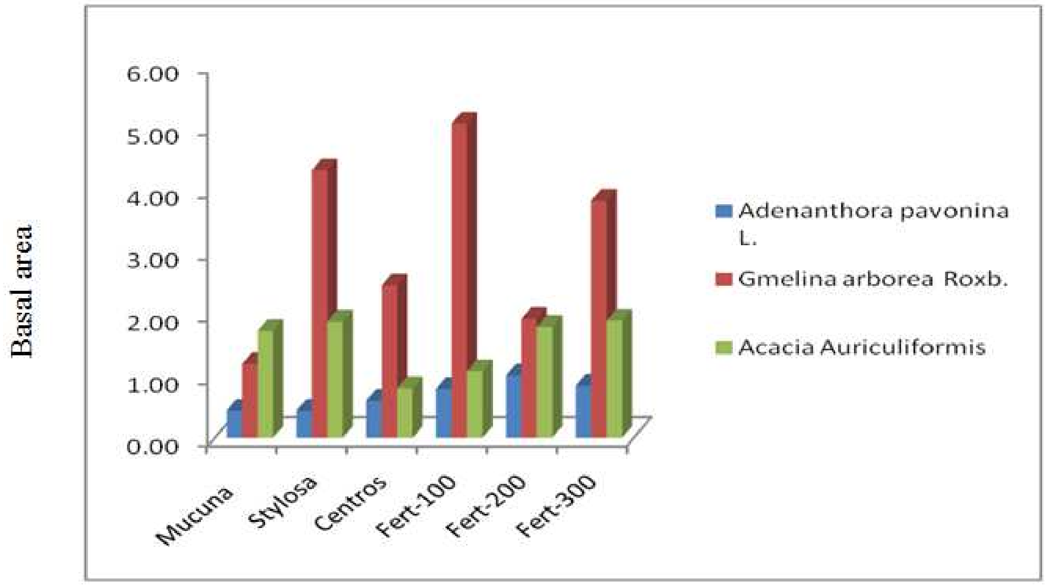

Figure 4: Leguminous Cover Crops and Fertilizer Applications in the Basal Area

Canopy Cover

Figure 5 summarizes the effect of different leguminous cover crop and fertilizer application on the canopy cover on the growth performance of the three species used in the study.

Adenanthera Pavonina

Here, *M. utilis* attained mean canopy cover (CC) of 78.13. *S. gracilis* attained mean canopy cover of 84.71. *C. pubescens* had 70.90. For fertilizer application, 100 NPK attained 83.17. 200 NPK attained mean canopy cover of 55.39. 300 NPK attained mean canopy cover of 62.59. At the end of the growth period, *S. gracilis* grown under *A. pavonina* had the highest mean canopy cover of 84.71.

There is a significant difference among the treatments over time. At the end of the growth period, *S. gracilis* had significantly the highest mean canopy cover of 84.71 when compared with the control (*M. utilis* – 78.13). 200 NPK recorded the least ($P \leq 0.05$) mean canopy cover of 55.39 over time when compared with the control. There is a significant difference among location in months of the canopy cover. At the end of the growth period, *S. gracilis* had significantly the highest canopy cover of 157.11 in September 2018. However, in terms of treatment and location interactions over time, 157.11 recorded by *S. gracilis* in September 2018 were significantly highest irrespective of treatment and location.

Gmelina Arborea

Here, *M. utilis* attained mean canopy cover of 73.11. *S. gracilis* attained mean canopy cover of 7.74. *C. pubescens* had mean canopy cover of 67.53. 100 NPK attained mean canopy cover of 44.84. 200 NPK had a mean canopy cover of 64.29, while 300 NPK attained 45.39. At the end of the growth period, *M. utilis* recorded the highest mean canopy cover of 73.11 as the control.

There is a significant difference among the treatments over time. At the end of the growth period, *M. utilis* had significantly the highest mean canopy cover of 73.11 as the control. 100 NPK had the least ($P \leq 0.05$) mean canopy cover of 44.84 over time when compared with the control (*M. utilis* – 73.11). There is a significant difference among location in months of the canopy cover. At the end of the growth period, 200 NPK had the highest canopy cover of 193.35 in

September 2018. However, in terms of treatment and location interactions over time, 193.35 recorded by 200 NPK in September 2018 were significantly highest irrespective of treatment and location.

Acacia Auriculiformis

Here, *M. utilis* attained mean canopy cover of 105.02. *S. gracilis* had a mean canopy cover of 160.46. *C. pubescens* had attained a mean canopy cover of 159.66. 100 NPK attained mean canopy cover of 90.13. 200 NPK attained mean canopy cover of 139.31 while 300 NPK attained mean canopy cover 235.84. At the end of the growth period, 300 NPK had the highest mean canopy cover of 235.84. The least ($P \leq 0.05$) was 100 NPK with a canopy cover of 90.13 when compared with the control (*M. utilis* 105.02).

There is a significant difference among the treatments over time. At the end of the growth period, 300 NPK had significantly the highest mean canopy cover of 235.84 when compared with the control. 100 NPK had the least ($P \leq 0.05$) mean canopy cover of 90.13 over time. There is a significant difference among location in months of the canopy cover where, at the end of the growth period, 300 NPK had the highest canopy cover of 372.39 in October 2018. However, there is also a significant difference among treatment and location interactions over time. 300 NPK recorded the highest canopy cover in October 2018 irrespective of treatment and location.

In summary, the study revealed that *A. auriculiformis* had the highest mean canopy cover in all the treatments used. The least was *G. arborea*. The study also revealed that 300 NPK was the best fertilizer application for optimal canopy cover production of *A. auriculiformis*. Among the leguminous cover crop, the study revealed that *S. gracilis* and *C. pubescens* were the best leguminous cover crops for high canopy cover production of *A. auriculiformis.*

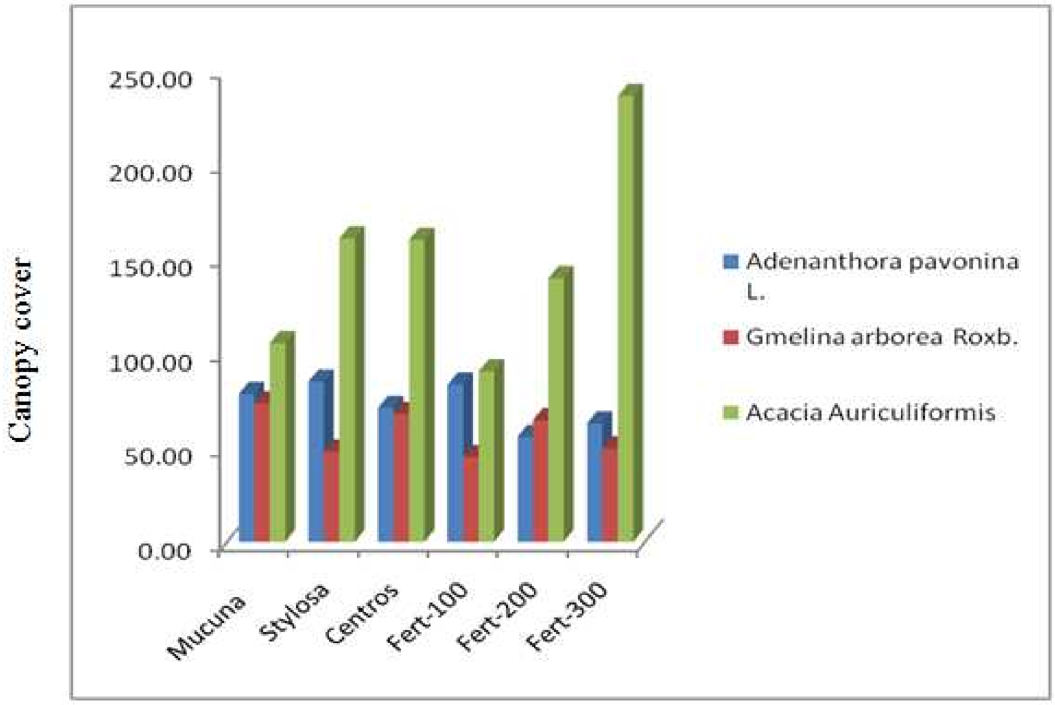

Figure 5: Leguminous Cover Crops and Fertilizer Applications on Canopy Cover

Relationship among the Tree Growth Parameters and Soil Properties Studied

Table 2: Relationship among the Soil Properties and Tree Growth Parameters Studied

	PlH	SG	CS	BA	CC
PlH					
SG	0.882**				
CS	0.792**	0.872**			
BA	0.788**	0.956**	0.809**		
CC	0.537*	0.549*	0.767**	0.428*	
pH	0.233ns	0.242 ns	0.355*	0.250 ns	0.234 ns
TN	0.024 ns	0.107 ns	-0.014 ns	0.095 ns	0.039 ns
AvP	-0.121 ns	0.011 ns	-0.039 ns	-0.005 ns	-0.022 ns
K	0.355*	0.498*	0.315 ns	0.499*	0.003 ns
TEA	0.235 ns	0.158 ns	0.109 ns	0.163 ns	0.055 ns
ECEC	0.028 ns	0.007 ns	-0.025 ns	-0.012 ns	0.114 ns
%BS	-0.184 ns	-0.088 ns	-0.099 ns	-0.094 ns	-0.049 ns
MC	-0.166 ns	-0.279 ns	-0.300 ns	-0.308 ns	-0.160 ns
Ca	-0.081 ns	-0.066 ns	-0.095 ns	-0.094 ns	0.016 ns
Mg	-0.066 ns	-0.013 ns	-0.043 ns	-0.023 ns	0.104 ns
Na	0.028 ns	-0.001 ns	0.016 ns	-0.017 ns	0.005 ns
Al	-0.218 ns	-0.001 ns	-0.146 ns	-0.007 ns	-0.132 ns
Sand	0.174 ns	0.238 ns	0.188 ns	0.312 ns	0.102 ns
Silt	-0.051 ns	-0.129 ns	-0.085 ns	-0.189 ns	-0.044 ns
Clay	-0.252 ns	-0.272 ns	-0.237 ns	-0.331 ns	-0.132 ns
BD	0.236 ns	0.278 ns	0.354*	0.237 ns	0.346*
TP	-0.236 ns	-0.279 ns	-0.354*	-0.237 ns	-0.347*
Ksat	-0.313 ns	-0.284 ns	-0.315 ns	-0.243 ns	-0.243 ns

Key: plH= Plant Height, SG= Stem Girth, CS = Canopy Sectional Area, BA= Basal Area, CC= Canopy Cover, OM= organic matter, TN=total nitrogen, AVP=available phosphorus, TEA=total exchangeable acidity, ECEC=effective cation exchange capacity, %BS= percentage base saturation BD=bulk density, TP=total porosity, MC=moisture content, Ksat=saturated hydraulic conductivity.

Plant Height

There is a significant difference between the plant height and stem girth, canopy sectional area, basal area, canopy cover, and Potassium. Increase in plant height significantly increased stem girth, canopy sectional area, basal area, canopy cover, and potassium

There is no significant difference found between plant height and pH, total nitrogen (TN), available Phosphorus (AVP), Total Exchangeable Acidity (TEA), Effective Cation Exchange Capacity (ECEC), Percentage Base Saturation (%BS), Moisture Content (MC), Calcium (Ca), Magnesium (Mg), Sodium (Na), Aluminum (Al), Sand, Silt, Clay, Bulk Density (BD), Total Porosity (TP) and Saturated Hydraulic Conductivity (Ksat).

Stem Girth

There is a significant difference between the stem girth and canopy sectional area (CSA), basal area (BA), canopy cover (CC), and Potassium (K). Increase in stem girth significantly increased the CSA, BA, CC, and K.

No significant difference was found between pH, TN, AVP, TEA, ECEC, %BS, BD, TP, Ksat.

Canopy Sectional Area

There is a significant difference found among basal area, canopy cover, pH, BD, and TP. Increase in canopy sectional area significantly increased basal area, canopy cover, pH, BD, but increase in canopy sectional area significantly decreased TP

There is no significant difference between CSA and TN, AVP, K, TEA, ECEC, %BS, MC, Ca, Mg, Na, Al, Sand, Silt, Clay, Ksat.

Basal Area

There is a significant difference among basal area and canopy cover and Potassium. Increase in the basal area significantly increased canopy cover and Potassium.

There is no significant difference found in pH, TN, AVP, TEA, ECEC, %BS, MC, Ca, Mg, Na, Al, Sand, Silt, Clay, BD, TP, and Ksat.

Canopy Cover

There is a significant difference between canopy cover and Bulk density. Increase in canopy cover significantly increased bulk density. There is also a significant difference between canopy cover and Total Porosity (TP). Increase in canopy cover significantly decreased TP.

There is no significant difference found between canopy cover and pH, TN, AVP, K, TEA, ECEC, %BS, MC, Ca, Mg, Na, Al, Sand, Silt, Clay and Ksat.

DISCUSSIONS

Plant Height

The study showed that *Acacia auriculiformis* had the highest plant height in all the treatments used. Trees are sometimes considered in restoring degraded mined soils. 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. Blum (1988) indicated that their deep roots involve a greater depth of the raw mine stones than grass and, with a little encouragement penetrates to the less compacted spoil layers beneath the “cap” of trapped clays. 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 reach roots of understorey herbaceous vegetation, reduce loss of nutrients by erosion and leaching.

Acacia auriculiformis was the best tree for rehabilitation in that, the leaf litters prevent the direct impact of torrential raindrops on soils and impede the movement of runoff as well as preventing further erosion on the de-surfaced soil. This is in line with the finds of Bonsu *et al*. (1996); Anane-Sakyi (1995); Ingram (1999). Agboola (1990) also reported that nutrients move from the soil to the mat layer to the vegetation, and back to the soil and mat layer through the litterfall. The mat layer mechanism also serves as a means for nutrient conservation because most of the nutrients are located in the mat of roots and humus that occur on or near the soil surface. The more the litter produced under fallow, the more fertile the land. Ingram (1999) reported several processes have been identified by which trees can enhance the chemical and physical properties of the soils. Troeh *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, results in the improvement of soil hydrophysical and chemical properties.

Increase in fertilization application increased plant height of *A. auriculiformis*. This is in line with what Homma and Horie (2009) reported in rice yield. Among the leguminous cover crop application, *Stylosanthes gracilis* was the best for *A. auriculiformis* optimal plant height production. This supports Ngome *et al.* (2011) findings. They reported that when a leguminous cover crop is incorporated into the soil, a substantial amount of nitrogen is usually mineralized, converted from organic to plant-available forms within a few weeks. They stated further that the application of *Calopogonium mucunoides* increased both total N and available P in the soil. Meanwhile, the increase in soil available P could be partly due to presence of beneficial fungi known as mycorrhizae housed by the roots of leguminous cover crops which accumulates P. The filaments (hyphae) of these fungi effectively extend the root systems and help the leguminous cover crops tap more soil P (Ngome *et al.* 2011).

Stem Girth

Gmelina arborea had the highest stem girth in almost all the treatments used. The *G. arborea* tree attains moderate to a large height up to 30m with the girth of 1.2 to 4 (Singh *et al*. 2004; Singh and Singh, 2006 and Russell, 1973). They also stated that *G. arborea* does not thrive on ill-drained soils and remains stunted on dry, sandy or poor soils (ex-stone quarry site); drought also reduces it to a shrubby form. *G. arborea* sown under 100 NPK fertilizer applications attained the highest mean stem girth at the end of the experiment. This result concurs with a report by Elsworth and Paley (2009) which stated that the effect of fertilization application depends on species of plant. In terms of the effect of leguminous cover crops on stem girth, *Stylosanthes gracilis* was the best for *G. arborea* production (Singh and Singh, 2006). Leguminous cover crops may have substantial effects on several components of agroecosystems. Hanna *et al*. (1995) stated that leguminous cover crops served as an alternative to nitrogen fertilizers. Recent studies indicated that graminaceous cover crop species can improve the Fe-nutrition of fruit trees grown on calcareous soils by enhancing Fe-availability (Rombola and Tagliavini 2006; Cesco *et al*. 2006).

Canopy Sectional Area

A. auriculiformis had the highest mean canopy sectional area in all the treatment used. Litter from *A. auriculiformis* tends to cover the surface of the soil more than other trees used in the study. This litter tends to store water or moisture in the soil and also prevents weeds from growing beneath the trees. The litter also aid in adding nutrients to the soil, hence encouraging more growth and canopy sectional area. This result concurs with a report by Young (1997). He pointed out that, of all the effects of trees that of maintaining soil organic matter levels through the supply of litter and root residues is the major cause of soil fertility improvements. It is the major mover of nutrients, from which stems many of the other soil improving processes. Consequently, from the study carried out by Aggawal (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. It was observed that soils under vegetation had accumulated higher Nitrogen, Phosphorus and Potassium than those under open field. This is due to the increased supply of litter provided by the vegetation which contributes organic matter, which in turn decomposes to release nutrients and that are responsible for improvement in soil fertility on degraded mined lands. This justifies the research by Ingram (1999) and Troeh *et al.* (1980) who indicated that the increased supply of litter (above and below ground residues) under natural fallow is considered to be responsible for the maintenance of soil organic matter and improvement in soil productivity of degraded lands. For instance, Felker (1978) reported *Acacia albida* cases of 50 to 100% increases in organic matter and nitrogen under the canopy are known, together with increased water holding capacity. Young (1989) also noted that in semi-arid climates, it is common to observe higher soil organic matter and nutrient content under tree canopies than in adjacent open land. 300 NPK fertilization applications were the best for high canopy sectional area of *A. auriculiformis* (Homma and Horie, 2009).*S. gracilis* was the best for optimal canopy sectional area of *A. auriculiformis* (Ngome *et al.* 2011).

Basal Area

G. arborea had the highest mean basal area in all the treatments used. Increase in stem girth tends to increase the basal area. *G*. *arborea* recorded the highest stem girth in all the treatments used; consequently, this will increase the basal area (Singh *et al*. 2004; Singh and Singh 2006). The basal area of *G. arborea* was more in 100 NPK fertilization applications. For optimal growth of the plant, application of NPK fertilization depends on plant species (Elsworth and Paley, 2009). They stated further that plant may require low, moderate or high fertilization application for it to grow. Low NPK fertilization application may decrease or increase growth performance and vice versa. Its effect depends on the plant species. *S. gracilis* was also the best leguminous cover crop for the high basal area of *G. arborea* (Ngome *et al.* 2011).

Canopy Cover

A. auriculiformis had the highest mean canopy cover in all the treatments used (Young, 1997 and 1989; Aggawal, 1980). 300 NPK fertilizer applications were the best for high canopy cover of *A. auriculiformis* (Homma and Horie, 2009). *S. gracilis* and *Centrosema pubescens* were the best leguminous cover crops for high canopy cover of *A. auriculiformis* (Ngome *et al*. 2011; Hanna *et al.* 1995; Elsworth and Paley 2009).

CONCLUSIONS

From the study, the best tree for rehabilitating and restoring the quarried site was *Acacia auriculiformis*. For optimal growth performance of trees for restoring an ex-stone quarry, 300 NPK fertilizer applications were the best. Among the leguminous cover crops used, *Stylosanthes gracilis* was the best for optimal growth of the tree species used.

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