African Multidisciplinary
Journal of Sciences and Artificial Intelligence

ISSN : 1595-7969

Index: Harvard, Boston, Sydney University, Dimensions, Lens, ResearchGet Scilit, Semantic, Google Scholar, Base etc

https://doi.org/10.58578/AMJSAI.v2i2.6351

Effects of Pulverized Composting Methods on the Early Growth and Development of *Khaya senegalensis* in Maiduguri, Nigeria

Garba Musa[1], Edward Ephraim Dishan [2], Mohammed Alimu Gupa[3]
[1,3]University of Maiduguri Borno State, Nigeria
[2]Modibbo Adama University Yola, Adamawa State, Nigeria
musagarba101@unimaid.edu.ng

Article Info:

Submitted:	Revised:	Accepted:	Published:
May 11, 2025	Jun 6, 2025	Jun 18, 2025	Jun 23, 2025

Abstract

This study evaluated the effects of pulverized composting methods surface and subsurface on the early growth and development of *Khaya senegalensis* in Maiduguri, Nigeria. Foliage from *Khaya senegalensis*, *Gmelina arborea*, *Syzygium cumini*, and *Ziziphus spina-christi* was collected within the University of Maiduguri premises, sundried, and pulverized using a motorized disc refiner. The pulverized materials were categorized as composting treatments (M1–M4) and subjected to decomposition for 30, 60, and 90 days at both surface (0 cm) and subsurface depths (45 cm, 60 cm, and 75 cm). Macro (N, P, K, Ca, Mg) and micro (Mn, Cu, Zn, Fe) nutrient compositions were analyzed before and after the 90-day composting period. Potting media were prepared using river sand and compost in a 3:1 ratio. Seeds of *Khaya senegalensis* were sown at a depth of 3 cm, and growth parameters number of leaves (NOL), stem height (SHT), and stem diameter (SDM) were monitored weekly. Data were analyzed using ANOVA, regression, t-tests, and LSD for mean separation. Results indicated that compost derived from *Gmelina arborea* consistently yielded the lowest values for growth parameters over the eight-week period. Significant differences were observed in developmental traits such as root length, plant fresh and dry weights, root and

AMJSAI Journal is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

leaf fresh weights, turgid weight, and leaf area, while root dry weight did not differ significantly across treatments. Analysis of composting methods revealed no significant differences ($p < 0.05$) in stem height and stem diameter throughout the observation period, though a variation in leaf number was noted at week six. This discrepancy may be attributed to differences in microbial activity and nutrient mineralization across composting methods.

Keywords: Pulverization; Composting Method; Growth and Developmental Parameters; *Khaya senegalensis*; Organic Amendments

INTRODUCTION

A great diversity of trees, shrubs and herbs exist in the Semi-Arid region particularly Maiduguri and its Environs, however due to the overpopulation through influx to Maiduguri, exploitation of timber and non-timber forest resources, communal and security conflicts and natural disasters in the semi-arid zone of Nigeria, the availability of trees for utilization, protection and conservation of environment becomes a major concern. The survival of trees in either natural or artificial forest depends largely on the growth, developmental and survival of the seedlings. Furthermore, Seedling growth and- survival is a function of nutrients availability and subsequent uptake by plants. Composting helps in breaking down lumps of organic matter there by increase the nutrient status of the soil inform of compost and enhance productivity (Morales and Wolf, 2010). Composting therefore refers to the biodegradation process of a mixture of organic substrate by bacteria (actinomycetes) and fungi (Day and Shaw, 2001). However, composting differs from other decomposition systems due to control in temperature and rate of decomposition (Misra *et al.,* 2003). Compost is widely used for agriculture and horticulture especially on poor soils. Compost applications result in a range of environmental benefits which include improved soil health, water savings, reduction in the use of synthetic fertilizer and improved crop productivity (Schroth *et al*., 2003). According to Tejeda *et al.* (2009) a primary benefit of compost application on soil physical properties is to reduce bulk density and increase total porosity. However, compost application can improve soil structural stability, aggregate formation and hydraulic conductivity (Curtis and Claassen, 2005). Lakhdar *et al.* (2009) reported that compost application changes soil chemical properties and increases soil nutrients, efficiency of nutrients and partial replacement of inorganic fertilizer. Compost application improves soil fertility by increasing the concentration of nitrogen, phosphorus, and potassium (NPK) and other nutrients (Castillejo and Castello,

2010). However, the effect varies with application rate and compost type. Compost is a valuable slow release nitrogen source with a stronger residual effect on soil fertility than chemical fertilizers (Krause *et al.* 2015). Compost increases the concentration of other nutrients such as calcium zinc, manganese, and copper (Mylavarapu and Zinati, 2009). While Composting is a natural process of biological decomposition and stabilisation of organic waste (Schulz *et al.*, 2013). The nutrient- rich final product that can be applied to land as soil fertilizer or stabilizer offers significant benefits to agro-ecological systems as it combines environmental protection with sustainable agricultural production (vandecasteele et al. 2016. The improvement of soil properties is a major benefit of compost application (Krause *et al.* 2015).

Composting has also been gaining increasing attention as an alternative way of waste processing. In addition to the organic fraction of municipal solid waste (MSW), it is now also being adapted for treatment of various other types of organic waste such as farm manures, sewage sludge, and industrial sludge (Fiscer and Glaser,2012). Indeed, the composting process has the ability to reduce pathogenic bacteria, viruses, and parasites in such waste material, which could otherwise pose a health risk. Although pathogens cannot be eliminated completely via composting, the presence of pathogens in litter compost is lower than in livestock manures (Wébster and Fransis, 2016). Composting is a natural process of biological decomposition and stabilisation of organic waste (Schulz *et al.*, 2013). The nutrient- rich final product that can be applied to land as soil fertilizer or stabilizer offers significant benefits to agro-ecological systems as it combines environmental protection with sustainable agricultural production (vandecasteele et al. 2016. The improvement of soil properties is a major benefit of compost application (Krause *et al.* 2015).

Composting has also been gaining increasing attention as an alternative way of waste processing. In addition to the organic fraction of municipal solid waste (MSW), it is now also being adapted for treatment of various other types of organic waste such as farm manures, sewage sludge, and industrial sludge (Fiscer and Glaser,2012). Indeed, the composting process has the ability to reduce pathogenic bacteria, viruses, and parasites in such waste material, which could otherwise pose a health risk. Although pathogens cannot be eliminated completely via composting, the presence of pathogens in litter compost is lower than in livestock manures (Wébster and Fransis, 2016). There are two main types of composting: cold composting (known as passive composting) and hot composting (known as active composting) ((Meiuer, *et al.,* 2009). Cold composting breaks down organic matter slowly, but

also takes the least amount of effort and maintenance. Cold composting process is primarily anaerobic, meaning that the organic materials are broken down by microorganisms that thrive in an oxygen-deprived environment (Bar and Ori, 2014). In addition to being slower to break down, cold piles may be smelly (Bar and Ori, 2014). Hot composting is faster but involve more management process: this method requires attention to keep carbon and nitrogen in the optimum ratio (Bar and Ori, 2014). However, composting is classified as pit /subsurface and open space/surface composting (Wetbrench, *et al.,* 2011). A pit composting is a hole purposely created in the ground where organic materials are added, such as food scraps, yard waste and leaves. Over time, these materials breakdown into compost which is a rich nutrient soil amendments that can be used to enhance the quality of soils (Wetbrench, *et al.,* 2011). In addition, subsurface composting is a process that involves a designated area or structure where organic material are deposited and allow to decompose naturally (Nonogaki, *et al.,* 2010). Subsurface composting provides a controlled environment for breakdown of organic matter, promoting the growth of beneficial microorganisms that facilitate the composting process. Subsurface composting process usually takes several weeks to several months depending on the material used and the environmental condition.

Surface or open composting essentially comes down to creating an aerated pile of compost somewhere outside in a small hall/container or bare earth (Nonogaki, *et al.,* 2010). This method takes longer time to create usable compost. It requires no physical turning, with proper airflow system, compost piles can be built on a large scale, saving on total and use time (Wetbrench, *et al.,* 2011).

MATERIAL AND METHODS

Study area

The experiment was conducted in the Nursery site of the Department of Forestry and Wildlife, University of Maiduguri in Jere Local Government of Borno State, Nigeria. Jere local government lies within Latitude 11° 50‟‟and12° 05‟‟N and Longitude 13°.50‟‟and 12°.20‟‟ E. of the equator (Fig. 1). Jere local Government occupies a total landmass of 868 square kilometers at an elevation of 306 meters (1,004 feet) (Borno State Ministry of Land and Survey (MLS), 2008).

Climate / Vegetation

Jere local government is typically of dry tropical climate with distinct wet and dry season. Months of March and April are the hottest periods of the year with temperature ranging from 30^0C to 40^0C respectively. It is usually cold and dry during hamattan period (November to January). The area has an annual rainfall range of 500-700mm per annum

Nigerian Metrological Agency (NIMET, 2008). Jere local government lies in the SudanoSahelian ecological zone characterized by trees and vast grassland: the grasses are seasonal and disappear during dry season (DMS, 1992).

The study area has the following grasses; *Cyperus rotundus, Cyperus arenarius,Cynodon dactylon* and some trees species which include: *Acacia Senegal, Balanite aegyptica, Piliostigma thonningii, Adansonia digitata, Azadirachta indica, Eucalyptus camaldulensis, Calotropis procera, Acacia nilotica* with some shrubs as follows; *Dichrostachys cinerea, Grewia bicholor,Ziziphus mucuronata*.

Demographic Characteristics of the Study Area.

According to the 2006 census, Jere Local Government Area was estimated to have a population of 211,204 people, National Population Commission (NPC, 2006) while the projected population was estimated as 306,400 people as at March, 2022. Its residents are mostly Kanuri, Hausa, Shuwa, Babur/Bura, Marghi, Fulani and other ethnic groups. However, there is also considerable population of people from southern part of the country such as Igbo, Ijaw, and Yoruba (Borno State Agricultural Development Program. (BOSADP), 2008). Majority of the inhabitants are farmers, traders and few civil servants

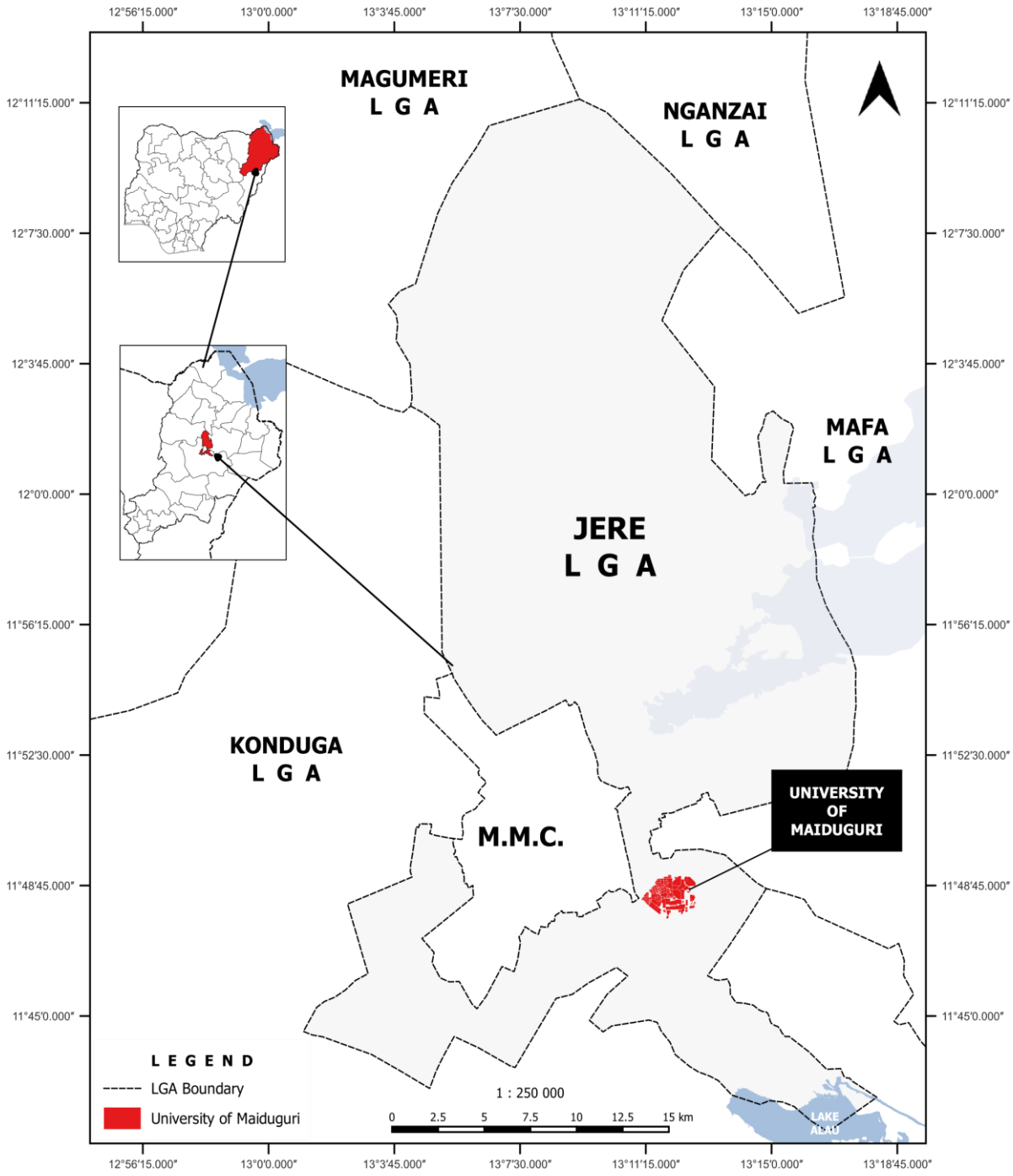

Fig. 1: Map of Jere Local Government Showing the Study Location.

Source: Cartographic Unit, Department of Geography, University of Maiduguri

Collection of Samples for Composting

Dried leaves of *Azadirachta indica, Gmelina arborea, Eucalyptus camaldulensis* and *Zizipus spins-christi* were collected within the premises of the University of Maiduguri. The collected leaves will be sundried to aid pulverization using a motorized disk refiner. Two (2) kilogram

(kg) of each pulverized composting materials was used to form the materials for composting: M_1 (Ks), M_2 (Ga), M_3 (Zc), M_4 (Zs). (M_1-M_4) (Abebe *et al,* 2000) and the control experiment M_0. The pulverized materials were poured into polythene sacks and buried at a depth of subsurface: 45cm, 60cm and 75cm while the surface method remained in plastic containers for composting.

Procedure for Composting

Pit composting (subsurface) and surface composting was adopted in line with Kuo (2004) procedure. With regards to pit composting, the pulverized foliar materials after collection undergo pulverization using motorized disc refiner, two kilogram (2kg) of pulverized foliar materials was used in a polythene sacs and buried at 45cm, 60cm and 75cm depths, while another 2kg of same pulverized foliar materials were poured in tight polythene sac containers and kept in open spaces for composting for 30 days, 60 days and 90 days respectively. Systematically, 90 days sample was buried first followed by 60 days sample and lastly by 30 days sample. The composts were turned through the vent and added two liters of water every 15 days throughout the composting duration of 90 days. At the end of the composting period (90 days), all the pulverized composts were ready and was applied to the potting medium which was used to raise the seedlings of *K senegalensis and Syzigium cumini* for the experiment.

Treatments and Experimental Design

Pulverized foliar of selected tree species for the experiment were form into five groups (M0, M1, M2, M3, M4,) and buried for composting in 45cm, 60cm and 75cm pits for 30, 60 and 90 days. The materials are as follows: M0 (no compost), M_1 (Ks), M_2 (Ga), M_3 (Zc), M_4 (Zs). Where:

Ks=*Khaya senegalensis*

Ga=*Gmelina arborea*

Sc=*Syzygium cumini*

Zs=Zizipus spina-christi

M0= Control (no composting material)

The experiment comprised of two methods of composting (pit/subsurface and surface), two species to test the treatments, three different composting depth, three different composting duration with three replications. The experiment is factorial and was arranged in

2x2x3x4 (RCBD) with three replications (Table 1). The factors include the pulverized composting materials, composting durations and methods of composting subjected to somes tree species.

Data Collection

Percentage of mineral compositions (Macro nutrients; N.P.K.Ca.Mg and Micro nutrients; Mn, Cu, Zn and Fe) of each compost mixture was determined in the laboratory after collection before pulverization and at the end of the composting period of 90 days using standard laboratory methods. Data on seedling growth/development parameters were collected for eight weeks starting after seedling establishment. Stem diameter (mm), stem height (cm) and number of leaves were collected and recorded on weekly bases, while root length (cm) and biomass (g) were measured at the end of the experiment.

Data Analysis

Regression analysis was used to ascertained the differences between surface and subsurface composting methods as follows:

$Y= a+b_1x_1$ (Linear Regression Adopted from Oxford Dictionary of Statistics)-

Equation 1

Where:

Y = Growth/development indices

X_1 = composting record a and b are constant.

Similarly, Analysis of Various was used for the growth and developmental paramaters.

Analysis of Variance (ANOVA)- - - - - Equation 2

The one way ANOVA tool that was used for this study is presented below:

ANOVA coefficient (F) = Mean sum of squares between the groups (MSB)/ Mean squares of errors (MSE). This can be simply express as;

F = MSB/MSE

Where;

Mean squares between groups (MSB) = SSB / (k– 1)

Mean squares of errors (MSE) = SSE / (N– k)

And

Total degree of freedom is N– 1= df3

Degrees of freedom of errors, N– k = df2 (N is the total number of observations throughout k groups).

Degrees of freedom between groups, k– 1= df1, where k is the number of groups.

RESULTS AND DISCUSSION

Multiple comparison between surface and subsurface foliar composting on growth parameters of *Khaya senegalensis* seedlings

The result obtained on surface and subsurface pulverized composting indicates that the values obtained for the growth parameters on seedlings of *K. senegalensis* showed variation (P≥0.05) on number of leaf (NOL) at week 6 while stem height (SHT) varied in weeks 2,3,7and 8. However, the value obtained on the *K.senegalensis* seedlings showed no variations

(P≥0.05) on number of leaf (NOL) at weeks 1,2,3,4,7 and 8, similarly, the results obtained did not show significance difference on stem height (SHT) at weeks 1,4 and 5. The result obtained equally showed no significant difference (P≥0.05) on stem diameter throughout the weeks (1-8). While developmental parameters: **RL=** Root length, **PFW**= Plant fresh weight, **PDW**= Plant dried weight, **RFW**= Root fresh weight, **RDW**= Root dried weight, **LFW**= Leaf Fresh weight, **LTW=** Leaf turgid weight, **LDW=** Leaf dried weight, **LA=** Leaf area, did not varied significantly (P≥0.05) (Table 1)

Table 1. Multiple Comparison of composting between Surface and Subsurface Parameters of *Khaya senegalensis*

Dependent Variable	Surface	Sub-Surface	Mean Difference (I-J)		Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
NOL wk1	LSD	0	45	-0.584	0.563	0.304	-1.710	0.540
			60	0.222	0.563	0.695	-0.910	1.350
			75	-0.167	0.563	0.768	-1.290	0.960
SHTcm wk1	LSD	0	45	-1.343	0.740	0.075	-2.826	0.141
			60	-0.275	0.740	0.712	-1.758	1.208
			75	-1.315	0.740	0.081	-2.798	0.168
SDMmm wk1	LSD	0	45	-0.197	0.147	0.185	-0.491	0.097

			60	0.021	0.147	0.888	-0.273	0.315
			75	-0.077	0.147	0.603	-0.371	0.217
NOL wk2	LSD	0	45	-0.833	0.710	0.246	-2.255	0.590
			60	-0.092	0.710	0.898	-1.514	1.330
			75	-0.249	0.710	0.727	-1.671	1.173
SHTcm wk2	LSD	0	45	-1.367	0.761	0.078	-2.891	0.157
			60	-0.390	0.761	0.610	-1.914	1.134
			75	-1.469	0.761	0.059	-2.993	0.055
SDMmm wk2	LSD	0	45	-0.217	0.163	0.189	-0.543	0.110
			60	0.027	0.163	0.870	-0.300	0.353
			75	-0.163	0.163	0.322	-0.489	0.164
NOL wk3	LSD	0	45	-0.943	0.668	0.164	-2.281	0.396
			60	0.001	0.668	0.999	-1.338	1.340
			75	-0.944	0.668	0.163	-2.283	0.395
SHTcm wk3	LSD	0	45	-1.429	0.814	0.085	-3.060	0.202
				-0.374	0.814	0.648	-2.005	1.257
				-1.82167*	0.814	0.029	-3.453	-0.191
SDMmm wk3				-0.244	0.167	0.149	-0.579	0.091
				0.000	0.167	1.000	-0.335	0.335
				-0.248	0.167	0.143	-0.583	0.086
NOL wk4	LSD	0	45	-1.140	0.657	0.088	-2.457	0.177
			60	0.074	0.657	0.911	-1.243	1.391
			75	-0.860	0.657	0.196	-2.177	0.457
SHTcm wk4	LSD	0	45	-1.620	0.922	0.084	-3.467	0.227
			60	-0.262	0.922	0.778	-2.109	1.585
			75	-1.608	0.922	0.087	-3.455	0.239
SDMmm wk4	LSD	0	45	-0.248	0.176	0.163	-0.601	0.104
			60	0.018	0.176	0.921	-0.335	0.370
			75	-0.233	0.176	0.192	-0.585	0.120
NOL wk5	LSD	0	45	-1.195	0.682	0.085	-2.561	0.171
			60	0.444	0.682	0.517	-0.922	1.810
			75	-0.833	0.682	0.227	-2.200	0.533
SHTcm wk5	LSD	0	45	-1.777	0.995	0.080	-3.770	0.217
			60	-0.205	0.995	0.838	-2.199	1.789
			75	-1.799	0.995	0.076	-3.793	0.195
SDMmm wk5	LSD	0	45	-0.258	0.193	0.188	-0.645	0.130
			60	0.039	0.193	0.840	-0.348	0.426
			75	-0.255	0.193	0.192	-0.642	0.132
NOL wk6	LSD	0	45	-2.25250*	0.819	0.008	-3.893	-0.612
			60	-0.447	0.819	0.588	-2.087	1.194
			75	-2.22417*	0.819	0.009	-3.865	-0.584

SHTcm wk6	LSD	0	45	-1.873	1.034	0.075	-3.945	0.199
				-0.232	1.034	0.824	-2.304	1.840
				-2.29417*	1.034	0.031	-4.366	-0.222
SDMmm wk6				-0.258	0.196	0.194	-0.652	0.135
				0.073	0.196	0.710	-0.320	0.467
				-0.295	0.196	0.139	-0.689	0.099
NOL wk7	LSD	0	45	-1.475	0.755	0.056	-2.989	0.039
			60	0.831	0.755	0.276	-0.683	2.344
			75	-1.142	0.755	0.136	-2.655	0.372
SHTcm wk7	LSD	0	45	-2.043	1.142	0.079	-4.331	0.246
			60	0.100	1.142	0.931	-2.188	2.388
			75	-1.815	1.142	0.118	-4.103	0.473
SDMmm wk7	LSD	0	45	-0.281	0.210	0.186	-0.701	0.139
			60	0.088	0.210	0.678	-0.332	0.507
			75	-0.220	0.210	0.298	-0.640	0.200
NOL wk8	LSD	0	45	-1.139	0.816	0.169	-2.775	0.497
			60	0.750	0.816	0.362	-0.886	2.386
			75	-1.250	0.816	0.131	-2.886	0.386
SHTcm wk8	LSD	0	45	-2.110	1.162	0.075	-4.438	0.218
			60	0.253	1.162	0.829	-2.076	2.581
			75	-2.288	1.162	0.054	-4.616	0.041
SDMmm wk8	LSD	0	45	-0.278	0.205	0.181	-0.688	0.133
			60	0.086	0.205	0.677	-0.325	0.496
			75	-0.291	0.205	0.161	-0.701	0.120
R.L(cm)	LSD	0		451.100	1.617	0.499	-2.141	4.341
			60	1.250	1.617	0.443	-1.991	4.491
			75	0.942	1.617	0.563	-2.300	4.183
PFW(g)	LSD	0	45	-0.494	0.689	0.476	-1.875	0.887
				-0.018	0.689	0.979	-1.400	1.363
				-0.211	0.689	0.761	-1.592	1.170
PDW(g)				-0.245	0.215	0.258	-0.675	0.185
				-0.075	0.215	0.728	-0.505	0.355
				-0.162	0.215	0.454	-0.592	0.268
RFW(g)	LSD	0	45	-0.162	0.197	0.415	-0.556	0.233
			60	0.006	0.197	0.976	-0.389	0.400
			75	0.009	0.197	0.963	-0.385	0.404
RDW(g)	LSD	0	45	-0.140	0.164	0.397	-0.468	0.188
			60	-0.029	0.164	0.859	-0.358	0.299
			75	0.089	0.164	0.588	-0.239	0.418

		-0.018	0.689	0.979	-1.400 1.363
LFW(g)	LSD	045-0.053	0.066	0.421	-0.185 0.079
		60-0.056	0.066	0.400	-0.188 0.076
		75-0.102	0.066	0.128	-0.234 0.030
LTW(g)	LSD	045-0.071	0.086	0.411	-0.242 0.101
		60-0.093	0.086	0.280	-0.265 0.078
		75-0.155	0.086	0.076	-0.327 0.017
LDW(g)	LSD	045-0.016	0.024	0.512	-0.064 0.032
		60-0.015	0.024	0.534	-0.063 0.033
		75-0.035	0.024	0.150	-0.083 0.013
LA(cm2)	LSD	045-3.128	4.575	0.497	-12.296 6.041
		60-3.043	4.575	0.509	-12.212 6.126
		75-5.732	4.575	0.216	-14.901 3.437

The mean difference is significant at the 0.05 level.

Source: Analyzed from Field Data, 2024

Key: RL= Root length, **PFW**= Plant fresh weight, **PDW**= Plant dried weight, **RFW**= Root fresh weight, **RDW**= Root dried weight, **LFW**= Leaf Fresh weight **LTW=** Leaf turgid weight, **LDW=** Leaf dried weight, **LA=** Leaf area, **0, 45, 60, 75** = Composting depths in centimeters (cm).

Composting procedure is important for the biodegradation of organic materials and the duration covered for the entire process. Composting refers to the biodegradation process of a mixture of organic substrate by bacteria, actinomycetes and fungi (Day and Shaw, 2001). These microbes attack, feed on and digest organic wastes, then these microbes are preyed upon by the second level of organisms e.g. protozoa and beetles, mites. The composting process has 3 stages: a rapid stage of decomposition, stabilization and humification (Insam and Bertodi, 2007), while Polprasent (1989) distinguishes 4 stages of composting. In the first stage, mesophilic bacteria are predominant and the temperature in the compost pile increases 35°C- 45°C. When the temperature exceeds 45°C, mesophilic bacteria are replaced by thermophilic bacteria The result obtained from the composting methods (surface and subsurface) in this research showed that there is no variation ($P<0.05$) between the composting methods on stem height and stem diameter throughout the eight weeks while the result varies on number of leaf (NOL) at week six. The variation in number of leaf could be due to the composting process involved which affects the microbial activities on breaking down the composting materials and mineralization process.

Similarly, the result obtained for developmental parameters ($P<0.05$) for comparison between surface and subsurface composting showed no significant difference. The non-variance of the effects of the composting methods could be due to the pulverization of the foliar materials that added the surface area for microbial activies invariably lessen their actions compared to the conventional composting. This correlate with the findings of…….

CONCLUSION

The result obtained from this study on the effect of surface and subsurface foliar composting on the growth and developmental parameters of *Khaya senegalensis* showed that pulverized foliar pit (Subsurface) composting showed significant effects on the tree seedlings. The variation could be due to the controlled (pit) composting procedure which is away from the direct contact with some pest, disease that could deterred the process such us odour, pathogen.

Acknowledgement

Authors are indeed thankful to the Department of Forestry and Wildlife, university of Maiduguri and the Chief Executive of University of Maiduguri for their support in providing facilities; Nusery site and the university campus space for conducting this research on the effect of composting methods on the growth and development of *Khaya senegalensis* in Maiduguri.

REFERENCES

Bar, M. Ori, N. (2014). Leaf development and Morphogensis. Development:14(22).

Castillejo, J. M., and Castello, R. (2010). Influence of the Application Rate of An organic Amendment (municipal solid waste [MSW] compost) on Gypsum Quarry Rehabilitation in Semi-Arid Environments, *Arid Land Research and Management* 24, 344-364.

Curtis, M. J. and claassen, V.P. (2005). Composts Incorporation increase plant available water in a Drastically Disturbed Serpentine soil. *Soil Science*, 170, 939-953

Day, M. and Shaw, k. (2001). Biolographical, Chemical and Physical Processes of Compositing. In *Compost Utilization in Horticultural Cropping System*; stofffela, PJ and Kaln, BA (Eds). Pp, 17-50 (Lewis publishers, bocaraton).

DMS (2002). Department of Metrological Service, Borno State, Nigeria

Fischer, D., & Glaser, B. (2012). Synergisms between compost and biochar for sustainable soil amelioration. In S. Kumar & A. Barthi (Eds.), *Management of organic waste* (pp. 167–199). Rijeka: InTech.

Insam, H. and De- Bertodi, M. (2007). Microbiology of the Compositing Process. *In Compost Science and Technology*, Volume 8 Waste Management. (Eds) pp.26-45. (Elsevier science, Amsterdam).

Krause, A., Kaupenjohann, M., George, E., & Koeppel, J. (2015). Nutrient recycling from sanitation and energy systems to the agroecosystem- ecological research on case studies in Karagwe, Tanzania. *African Journal of Agricultural Research, 10*(43), 4039–4052.

Kuo, S., Ortiz, M. E., Hue, N. V., and Hummel, R. L. (2004). Composting and compost utilization and container crops. *Soil Sci. Soc.* Am. J., 61. 1392.

Lakhdar, A., Rabh, M., Ghnaya, T., montemuro, F., Jedidi, N. and Abdelly, C. (2009). Effectiveness of Compost use in Sacl-affected Soil, *Journal of hazardous Materials*, 171, 29-37.

Meieru, U. Bleiholder, H. Buhr, L. Feller, C. (2009). The BBCH System to coding the phonological growth stages of plants. *History and publication journal,* 61,41-43.

Ministry of Land and Survey (MLS) (2008) Borno State. Borno Land Reports

Morales, G.E., Wolff, M.(2010). Insects associated with the composting process of solid urban waste separated at the souce. *Rev. Bras. Entomol.54, 645-653*

Mylavarapu, R.S. and Zinati, G.M. (2009). Improvement of Soil Properties Using Compost for Optimum Parsley Production in Sandy Soils, *Scientific Horticultures* 120, 426430.

NIMET (2008). Nigerian Metrological Agency, National Weather Forecasting and Climate Research Centre, Nnamdi Azikiwe International Airport, Abuja. Nigeria.

Nyoka, B.I.; Kamanga, R.; Njoloma, J.; Jamnadass, R.; Mng‟omba, S.; Muwanje, S. (2018). Quality of tree seedlings produced in nurseries in Malawi: An assessment of morphological attributes. *For. Trees Livelihoods*, *27*, 103–117.

Pinamonte, F. (1998). Compost Mulch Effects on Soil Fertility, Nutritional Status and Performance of Grapevine: *Nutrient cycling in Agro ecosystem*. 51, 239-248.

Polprasent, C. (1989). *Organic Waste Recycling*, (John Wiley and sons, Chichester United Kingdom).194-197.

Schroth, G., Vanlauwe, B. and Lehmann, L. (2003). Soil Organic Matter. In tree. Crops and Soil Fertility: *Concepts and Research Methods*. pp. 77- 89 (CABI publishing, cambridge).

Schulz, H., Dunst, G., & Glaser, B. (2013). Positive effects of composted biochar on plant growth and soil fertility. *Agronomy for Sustainable Development, 33*, 814–827.

Tejeda, M., Hernandez, M.T. and Garcia, C. (2009). Soil restoration using composed plant residence: Effects on soil properties, *Soil and Tillage Research*. 102, 109-117.

Webster, P., & Francis, R. (2016). Green shoots of success. Drivers and approaches towards a successful bioeconomy. *The Chemical Engineering, 900*, 24–28.

Wetbrench, K. Muller, K. Leubner, G. (2011). Early seed germination. J. Exp. Bot. 62:32893309.