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IMPACT OF PULVERIZATION ON NUTRIENTS STATUS OF SOME SELECTED FOLIAR MATERIALS BEFORE AND AFTER COMPOSTING IN SEMI ARID ENVIRONMENT

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ABSTRACT

This study assessed the impact of pulverization on the nutrient status of selected foliar materials before and after composting in Maiduguri, Nigeria. Leaf litters from Khaya senegalensis, Gmelina arborea, Syzygium cumini, and Ziziphus spina-christi were collected, sundried, and pulverized using a motorized disc refiner. The pulverized materials were labeled M1–M4 and analyzed for macro (N, P, K, Ca, Mg) and micro (Mn, Cu, Zn, Fe) nutrients before composting. Each 2kg sample was buried for 30, 60, and 90 days at 0cm, 45cm, 60cm, and 75cm depths for composting. Post-composting nutrient analyses were then conducted. Results revealed statistically significant ($P \leq 0.05$) increases in macro nutrients especially nitrogen (N), phosphorus (P), calcium (Ca), and magnesium (Mg) after composting, particularly at varying depths. At 0cm, N, P, Mg, and Zn showed significant changes. At 45cm, N, P, Ca, and Mg were significantly affected. At 60cm, significant differences were observed in N, Ca, and Mg. At 75cm, significant differences occurred in N, P, K, Mg, and Cu. Micro nutrients such as Mn, Fe, Zn, and Cu generally exhibited less variation before and after-composting.The findings suggest that pulverization enhances nutrient availability in compost, particularly for macro nutrients, supporting its use in improving soil fertility in semi-arid environments. Therefore, pulverizing foliar materials from the selected tree species before composting is recommended to optimize nutrient release for seedling production and sustainable-land-management.

Keywords: Pulverization, Composting, Macro nutrients, Micro nutrients

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, security conflicts and natural disasters affects the semi-arid zone significantly, the availability of trees and shrubs for utilization, protection and conservation of the immediate environment becomes a major concern. Trees and shrubs survival in natural or artificial (plantation) forest depends largely on the growth, developmental and survival of its seedlings. Furthermore, Seedling growth and- survival is a function of nutrients availability and subsequent uptake by plants through its roots. Composting helps in breaking down lumps of organic matter thereby increase the nutrient status of the soil inform of compost and enhance productivity (Morales and Wolf, 2010). Composting therefore refers to the natural biodegradation process that transform organic materials into a nutrient-rich soil conditioner called compost (Ruggeo *et al.,* 2019). However, composting differs from other decomposition systems due to the control in temperature and rate of decomposition (Misra *et al.,* 2023). Compost is widely used for agriculture and horticulture especially on poor soils.
The composting process has 3 stages: a rapid stage of decomposition, stabilization and humification (Insam and Bertodi, 2007). The composting process is characterized by four phases (Firstly). the initial mesophilic phase (10-42°C) during which the temperature rapidly rises and initiate organic matter decomposition, (Secondly). The mesophilic phase (45-70°C), which is distinguished by prolonged high temperatures due to the extensive metabolic activities undertaken by endogeneous microorganisms (Thirdly) the middle mesophilic phase (65-50°C) during which the temperature decreases allowing for re-establishment of the heat resisting microbes. (Fourthly) the finishing phase (50-23°C) during which the organic matter and the biological heat production stabilize (Amore, *et al.,* 2013).
Moreover, it is carried out by different classes of microbes such as mesophiles and thermophiles. Generally, mesophilic microorganisms which function best between 30 and 50°C initiate the composting process (Chen, *et al.,*2011). As microbial activity increases soon after compost piles are formed, temperatures and density within the piles also increases and the thermpphilic microorganisms take over at temperatures above 50 °C ().Compost increases the concentration of other nutrients such as calcium zinc, manganese, and copper (Mylavarapu and Zinati, 2009). The concentrations of P and K increase substantially during composting. Adekiya et al. (2020) found that after the composting process was completed, the concentration of P increased by 31% and K by 12%. The proportion of various P forms in compost is influenced by feedstock and composting methods (Tambone *et al.,* 2007) .
Pulverization refers to the mechanical process of reducing solid materials into fine particles or powder, typically through grinding, crushing, or milling. In the context of agriculture, forestry, and waste management, pulverization is applied to organic materials, such as plant residues, leaves, or crop waste, to enhance their utility in composting, soil amendment, or biomass applications (Adekiya et al., 2020). The process increases the surface area of the material, facilitating microbial activity, accelerating decomposition, and improving nutrient release efficiency (Li et al., 2022). Pulverization is particularly valuable in environments with challenging conditions, such as the semi-arid Sudano-Sahelian region, where organic matter decomposition is slowed by low moisture and humidity (Ibrahim & Yusuf, 2021).
In composting, pulverization transforms bulky organic materials, such as foliar residues from trees like *Khaya*

senegalensis or Syzygium cumini, into finer particles, which reduces the physical barriers to microbial access and enhances aeration within compost piles (Smith & Patel, 2023). This is critical for optimizing composting processes in arid ecosystems, where traditional methods are often time-consuming due to environmental constraints (Adebayo & Salami, 2022). Pulverized materials decompose faster because the increased surface area allows microorganisms to break down organic matter more efficiently, releasing essential nutrients like nitrogen, phosphorus, and potassium for plant uptake (Zhang et al., 2024).

The application of pulverized compost in nursery seedling production has shown promise for improving soil fertility and seedling vigor. For instance, pulverized foliar compost from species like *Gmelina arborea* or Ziziphus spina-christi can enhance soil structure and nutrient availability, supporting early growth in tree seedlings under semi-arid conditions (Oladipo et al., 2023). Moreover, pulverization can be tailored to specific composting methods, such as surface or subsurface techniques, which influence decomposition rates and nutrient dynamics (Jones & Brown, 2021). However, the efficacy of pulverization depends on factors like particle size, composting duration, and environmental conditions, which require further investigation in semi-arid contexts (FAO, 2023).

Recent studies highlight pulverization's role in sustainable agriculture and reforestation. For example, pulverized compost has been shown to improve soil microbial biomass and enzyme activity, leading to better nutrient cycling in degraded soils (Wang et al., 2025). Additionally, pulverization reduces the bulk density of compost, making it easier to apply in nursery settings and improving its integration into soil matrices (Adekiya et al., 2020). This research came into as a result on arid nature of sudano-sahelian ecosystems which encourages desertification, desert encroachment and biodiversity lost because of insufficient nutrients supply to support growth and development, hence the need to ascertain the nutrients status of some selected tree species from its litters for rapid plants growth and development.

MATERIALS AND METHODS

Study Area

The research was carried out in the Nursery site of Forestry and Wildlife Department, University of Maiduguri. University of Maiduguri is situated 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. 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

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 (Ogungbenro and Oladosu, 2023).

Vegetation

The study area is located in the sudano-sahelian ecosystem with sparse drought tolerant tree species, with short tiny grasses as follows: 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

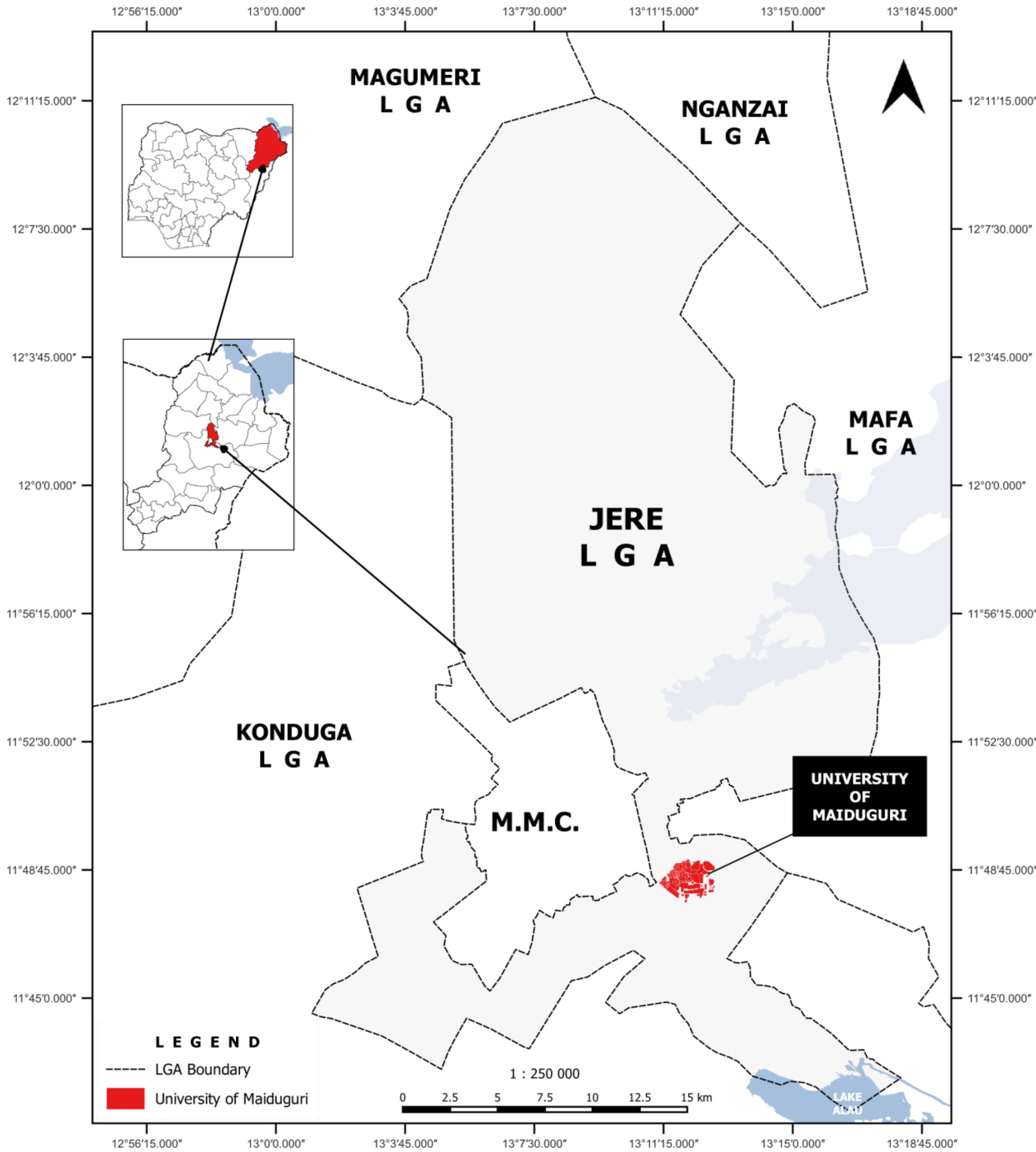

Figure 1: Map of Jere Local Government Showing the Study Location
Source: Cartographic Unit, Department of Geography, University of Maiduguri

Collection of Samples for Composting
Leaves of *Azadirachta indica, Gmelina arborea, Eucalyptus camaldulensis* and *Zizipus spins-christi* were collected as litters within the premises of University of Maiduguri. The collected foliar materials were further subjected to sun drying and subsequently pulverized using a motorized disk refiner. Some samples were collected raw for macro and micro nutrients analysis, while Two (2) kilogram (kg) of each pulverized foliar 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). The pulverized materials were poured into polythene sacks and buried at a depth of 45cm, 60cm and 75cm while the surface ones remained in open spaced for composting.

Procedure for Composting
After the pulverization, subsurface and surface composting was adopted in line with Kuo (2004) procedure. With regards to composting, pulverized foliar materials weighed two kilogram (2kg) and poured in a polythene sacs and buried systematically at 45cm, 60cm and 75cm depths for 30, 60 and 90 days composting durations started with the 90 days up to 30 days.ie 90 days sample was buried first followed by 60 days sample and lastly by 30 days sample. At the end composting period of 90 days, samples were taken from each compost and subjected it to micro and macro analysis.

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 after 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

Analysis of Variance (ANOVA)

One way ANOVA tool and T-test were used for this study to ascertain the variation and separate the mean values.

RESULTS AND DISCUSSION

Test of Differences Between the Micro and Macro Nutrients of Some Selected Foliar Materials Before and After Composting at 0cm Depths

The result obtained for the test of difference in pulverized foliar compost between micro and macro nutrients before and after composting at different composting depths (0cm.45cm,60cm,75cm) revealed that at zeros (0cm) depth the result varied significantly between pre and post composting of foliar materials on Nitrogen (N), Phosphorus (P), Magnesium (Mg), and Zinc(Zn) while the result showed no significant difference between Potassium(K), Manganese (Mn), Calcium (Ca) and Copper (Cu). (Table 1)

The analysis of micro and macro nutrients before and after composting at a 0cm depth revealed significant differences in the percentage of Nitrogen, Phosphorus, Magnesium, and Zinc. Conversely, Potassium, Manganese, Calcium, and Copper showed no variation in their nutrient status before and after composting. The observed variation in some nutrients could be attributed to the change in the nature of the materials (pulverization) and the exposed environment during composting. (Table 1)

The lack of variation in certain micro and macro nutrients might be due to the shallow depth or surface composting, which may not provide the required heat for optimal microbial activities, particularly mineralization. This aligns with Ebele *et al*. (2022), who reported that composting significantly impacts both macro and micro nutrients, improving overall soil health, and that composting affects the strength and availability of these nutrients depending on the nature of the composting materials (Table 1).

Table 1: Test of Differences Between the Micro and Macro Nutrients Before and After Composting of Foliar Materials 0cm Depth Paired Samples Test

Nutrients		Paired Differences					t	df	Sig. level
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	N - N0	1.82000	.41609	.20805	1.15790	2.48210	8.748	3	.003
Pair 2	P - P0	.10000	.06377	.03189	-.00147	.20147	3.136	3	.052
Pair 3	K - K0	-.29500	.20599	.10300	-.62278	.03278	-2.864	3	.064
Pair 4	Ca - Ca0	-1.85000	1.33791	.66895	-3.97891	.27891	-2.766	3	.070
Pair 5	Mg - Mg0	1.05000	.64869	.32435	.01779	2.08221	3.237	3	.048
Pair 6	Zn - Zn0	-.17000	.04243	.02121	-.23751	-.10249	-8.014	3	.004
Pair 7	Fe - Fe0	.02250	2.21047	1.10523	-3.49484	3.53984	.020	3	.985
Pair 8	Mn - Mn0	-.58500	.41388	.20694	-1.24358	.07358	-2.827	3	.066
Pair 9	Cu - Cu0	-.12500	.05447	.02723	-.21167	-.03833	-4.590	3	.019

Source: Analyzed from Field Data, 2024

Key: N= Nitrogen, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Zn= Zinc, Fe=Iron. Mn= Manganese, Cu= Cupper

Test of Differences Between the Micro and Macro Nutrients of Foliar Materials Before and After Composting at 45cm Depths

The result obtained for the test of difference in pulverized forliar compost between micro and macro nutrients before and after composting at 45cm composting depth revealed that the result varied significantly between pre and post composting of foliar materials on Nitrogen (N), Phosphorus (P), Calcium (Ca) and Magnesium (Mg), while the other results obtained showed no significant difference among Potassium (K), Magnesium (Mg), Zinc (Zn), Iron (Fe) and Manganese (Mn) . the results for the difference in micro and macro nutrients before and after composting showed that Nitrogen, Phosphorus, Calcium, and Magnesium varied significantly.

In contrast, Potassium, Magnesium, Zinc, Iron, and Manganese exhibited no variation between the composting materials before and after composting. The observed differences for some micronutrients in the foliar materials/compost before and after composting signify the impact of composting depth on the materials, which in turn affected the percentage nutrient status of the compost. The nutrient status of compost can vary depending on the type of organic materials used, the composting process, and the maturity of the compost. In terms of compost maturity, microbiological activity during the composting process can be used to determine compost maturity. This aligns with Jurado *et al*. (2014), who reported that compost maturity can be exhibited by the formation of microbial biomass, mesophilic and thermophilic bacteria, oxygen uptake rate, and CO_2 release during the composting process.

Vargas-García *et al*. (2010) also noted that changes in enzymatic activities during composting are recognized as biological indicators of compost maturity, as the degradation of organic matter is catalyzed by specific hydrolytic enzymes. This also aligns with Butler *et al*. (2011), who reported that high content of intermediate biochemical degradation by-products, including ammonia, sulfate, and short-chain organic acids, causes phytotoxic effects such as reduced seed germination, inhibited root growth, and diminished above-ground plant production. (Table 2).

Table 2: Test of Differences Between the Micro and Macro Nutrients in Foliar Materials Before and After Composting at 45cm Depth

Nutrients		Paired Differences					t	df	Sig. level
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	N - N45	2.17000	.77318	.38659	.93971	3.40029	5.613	3	.011
Pair 2	P - P45	.10000	.06633	.03317	-.00555	.20555	3.015	3	.057
Pair 3	K - K45	-.16750	.16879	.08440	-.43609	.10109	-1.985	3	.141
Pair 4	Ca - Ca45	-.87500	.54391	.27195	-1.74048	-.00952	-3.217	3	.049
Pair 5	Mg - Mg45	.91250	.91813	.45906	-.54845	2.37345	1.988	3	.141
Pair 6	Zn - Zn45	-.06000	.16062	.08031	-.31559	.19559	-.747	3	.509
Pair 7	Fe - Fe45	.30750	2.21303	1.10651	-3.21392	3.82892	.278	3	.799
Pair 8	Mn - Mn45	-.38250	.10782	.05391	-.55406	-.21094	-7.095	3	.006
Pair 9	Cu - Cu45	-.14500	.08963	.04481	-.28762	-.00238	-3.236	3	.048

Source: Analyzed from Field Data, 2024
Key; N= Nitrogen, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Zn= Zinc, Fe=Iron. Mn= Manganese, Cu= Cupper

Test of differences between the micro and macro nutrients in pulverized foliar materials before and after composting at 60cm depths

The result obtained for the test of difference between micro and macro nutrients in pulverized foliar materials before and after composting at 60cm depth revealed that the result varied significantly between pre and post composting of foliar materials on Nitrogen (N), Calcium (Ca) and Magnesium (Mg), while the other results obtained showed no significant difference among Phosphorus (P), Potassium (K), Magnesium (Mg), Zinc (Zn), Iron (Fe) and Manganese (Mn) (Table 3).. the results for the difference in micro and macro nutrients before and after composting at a 60cm composting depth indicated that Nitrogen, Calcium, and Magnesium varied significantly.

However, Phosphorus, Potassium, Magnesium, Zinc, Iron, and Manganese showed no significant difference. The variation between some nutrients before and after composting could be due to the depth of composting where some nutrients showed variability. Deep composting can cause limited oxygen, which reduces microbial activity, leading to slower decomposition and possible anaerobic conditions that cause nutrient losses due to denitrification. More aeration allows better nitrogen retention, but can increase ammonia volatilization. While in deeper layers, nitrogen can be lost due to anaerobic conditions leading to denitrification (loss of nitrogen) or ammonium accumulation (Prasad and Shivay, 2020). Furthermore, shallow composting allows for more microbial activity, which enhances phosphorus mineralization, making it more available. Conversely, deep composting warrants anaerobic conditions which can lead to phosphorus, potassium, calcium, and magnesium fixation, reducing their availability (Khater, 2015).

Table 3: Test of Differences between the Micro and Macro Nutrients Before and After Composting at 60cm Depth Paired Samples Test

Nutrients		Paired Differences					t	df	Sig. level
Pair 1	N - N60	1.82000	.49826	.24913	1.02715	2.61285	7.305	3	.005
Pair 2	P - P60	.09000	.06782	.03391	-.01792	.19792	2.654	3	.077
Pair 3	K - K60	-.29500	.19841	.09921	-.61072	.02072	-2.974	3	.059
Pair 4	Ca - Ca60	-1.12500	.26300	.13150	-1.54348	-.70652	-8.555	3	.003
Pair 5	Mg - Mg60	.80750	.81447	.40723	-.48850	2.10350	1.983	3	.142
Pair 6	Zn - Zn60	-.05000	.17224	.08612	-.32407	.22407	-.581	3	.602
Pair 7	Fe - Fe60	.79500	2.43240	1.21620	-3.07549	4.66549	.654	3	.560
Pair 8	Mn - Mn60	-.36000	.25456	.12728	-.76506	.04506	-2.828	3	.066
Pair 9	Cu - Cu60	-.10750	.03304	.01652	-.16007	-.05493	-6.507	3	.007

Source: Analyzed from Field Data, 2024
Key; N= Nitrogen, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Zn= Zinc, Fe=Iron. Mn= Manganese, Cu= Cupper

Test of differences between the micro and macro nutrients before and after composting at 75cm depths

The result obtained for the test of difference between micro and macro nutrients before and after composting at 75cm depths shows that the result varied significantly

($P \leq 0.05$) between pre and post composting of foliar materials on Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg) and Cupper (Cu) while the other results obtained showed no significant difference among Calcium (Ca), Zinc (Zn), Iron (Fe) and Manganese (Mn) (Table 4). At 75cm composting depth, result indicated that Nitrogen, Phosphorus, Magnesium, and Copper showed significant difference. In contrast, Calcium, Zinc, Iron, and Manganese did not show variation before and after composting. The variations obtained could be due to the deeper composting process, which is invariably slower decomposition due to oxygen limitations, potentially leading to incomplete composting and the formation of undesirable compounds like methane or hydrogen sulfide.

Deep composting can significantly affect the availability and transformation of some nutrients like calcium, zinc, iron, and manganese. Nutrient availability during composting is determined to a certain extent by the depth of the compost making; thus, deeper composting processes lead to nutrient immobilization, volatilization, leaching, acidification, over-decomposition of organic matter, and reduced efficiency of certain nutrients. This agrees with the report of Toledo *et al*. (2018) that deeper composting leads to nitrogen loss due to prolonged microbial activity and de-nitrification, and while phosphorus tends to be more stable, its availability can be affected by microbial activity and ph. Many complex organic compounds transform during the composting process under the catalysis of enzymes secreted by microbes. Furthermore, Yu *et al*. (2019) reported that nitrogen compounds transform through several biochemical reactions during the composting process, leading to the formation of nitrite and its emission in gaseous form.

Table 4: Test of Differences between the Micro and Macro nutrients in pulverized foliar materials before and after composting at different depth

Nutrients		Paired Differences					t	df	Sig. level
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	N - N75	2.13500	.25878	.12939	1.72322	2.54678	16.501	3	.000
Pair 2	P - P75	.12000	.07528	.03764	.00022	.23978	3.188	3	.050
Pair 3	K - K75	-.17000	.11343	.05672	-.35049	.01049	-2.997	3	.058
Pair 4	Ca - Ca75	-1.37500	1.69386	.84693	-4.07031	1.32031	-1.624	3	.203
Pair 5	Mg - Mg75	1.06500	.59000	.29500	.12618	2.00382	3.610	3	.036
Pair 6	Zn - Zn75	-.05500	.15927	.07963	-.30843	.19843	-.691	3	.539
Pair 7	Fe - Fe75	-.28500	2.75470	1.37735	-4.66834	4.09834	-.207	3	.849
Pair 8	Mn - Mn75	-.44250	.56091	.28046	-1.33504	.45004	-1.578	3	.213
Pair 9	Cu - Cu75	-.18500	.04435	.02217	-.25557	-.11443	-8.343	3	.004

Source: Analyzed from Field Data, 2024
Key; N= Nitrogen, P= Phosphorus, K= Potassium, Ca= Calcium, Mg= Magnesium, Zn= Zinc, Fe=Iron. Mn= Manganese, Cu=
Source: Analyzed from Field Data, 2024
Key; N= Cupper

CONCLUSION

In conclusion, the result obtained in this research for assessing the micro and macro nutrients from some selected pulverized foliar materials before and after composting showed that there is significant difference between most of the macro nutrients (N,P, Ca,Mg) before and after composting, similarly some micro nutrients (Mn, Fe, Cu) did not show significant difference before and after composting. Therefore, composting of pulverized foliar materials enhanced mineralization of macro and micro nutrients. It is recommended that pulverized foliage of *K. senegalensis, G. arborea, S.cumini and Z. spina-christi* should be subjected to composting before applying to raise seedlings which enhance nutrients for proper growth and development.

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