International Journal of Organic agricultural Research & Development
Volume 20 (1) (2025)

DECOMPOSITION AND NUTRIENTS RELEASE FROM FOLIAGE OF LEGUMINOUS TREE SPECIES IN THREE ALFISOLS SOIL

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ABSTRACT

Rejuvenating agricultural farming system to ensure continuous production and promoting soil fertility, leguminous tree leaves used as manure are potential alternative to commercial fertilizer for agricultural crop production. Hence, this study was carried out to investigate rate of decomposition and nutrients release from foliage of five leguminous tree species (*Albizia lebbeck*, *Acacia nilotica*, *Dalbergia sissoo*, *Delonix regia* and *Parkia biglobosa*) incorporated in three alfisols (sandy, loamy and clayey) at Bayero University Kano School Farm. The treatment consists of foliage of five leguminous trees in three alfisols soils and no incorporation as control resulting in a total of eighteen treatment in a completely randomized design (CRD) replicated three times using standard methods of laboratory analysis to determine macro and micro nutrients released over three months periods. The results obtained showed significant difference in macro and micro nutrients released in the three soils. Significantly higher amount of macro nutrients (organic Carbon, available Phosphorus and total nitrogen), CEC, micro nutrients (iron and zinc) and exchangeable bases (Ca, Mg, Na and K) were obtained from decomposed foliage of leguminous trees than the control, with *D. sissoo* foliage resulting in higher amount of nutrients than other foliage and control. Similarly, foliage incorporated in loamy soil resulted in higher release of nutrients than those recorded from clayey and sandy soils. The interaction of leguminous trees and soil types also had significant effect on nutrients released with *D. sissoo* incorporated in loamy soil having significantly higher nutrients released than all other treatment combinations. There were significant correlations among different soil properties as influenced by leguminous trees and soil types, and these variations could form the basis for their selection in improving degraded soil and to improve soil fertility in the study areas.

Keywords: Decomposition, Foliage, Alfisols, Nutrient, Leguminous trees

INTRODUCTION

Leguminous trees are members of the large plant family known as Leguminosae. They are an important element of the flora of savanna lands of Africa, distributed extensively from humid savannas of southern Guinea and derived savanna ecological zones to semi-arid savanna of the Sahel in the northern part of the region. The trees grow wild in savanna lands of Africa, but also widely retained in farmer's fields as a traditional agroforestry practice and afforded some measure of protection in both cultivated fields and bush fallow vegetation. They have various uses, such as food for humans, animal feed (including for grazing livestock in animal husbandry), ground cover for soil protection from erosion, and suppression of weeds (Dupriez and De Leener 1998). Additionally, they play a beneficial role in soil nutrient and fertility management (Mapfumo et al., 2001, Nwosu et al., 2011). Trees and shrubs contribute to food security and combat poverty, they provide fruits, wood and fodder for animals (Boffa 2000). Leguminous cover crops have been a common strategy used by farmers to enhance farm productivity (Rao and Mathuva, 2000; Ngome et al., 2011; Nwosu et al., 2011). Not only do they fix highly needed nitrogen to the soil through activities of microorganisms inhabiting their root nodules, the organic matter is rich in mineral elements such that they add significant amount to the soil through leaf litter fall (Nwosu et al., 2011). It was reported that soils in which legumes are either grown or incorporated, enhanced chemical, physical and biological properties (Rao and Mathuva, 2000; Nwosu et al., 2011; Ngome et al., 2011). Their vegetative matter is rich in mineral elements which when composted, could be used to enhance fertility of forest and agricultural soils effectively. With rise in population of Sudano-Sahelian zone of West Africa, integration of woody species with crop production will be effective and requires no monetary input to improve soil fertility (Bationo and Buerkert 2001; Wezel et. al., 2000). Soil fertility management in the tropics has become a major issue as a result of degradation due to rapid population growth (Fitzparick, 1986). In Nigeria, continuous cropping and intercropping has greatly reduce fertility of agricultural lands, to the extent that it could no longer supply nutrient required by crops for normal growth. Most of the soils in tropics are dominated by alfisols, utisols and oxisols with low activity clay. These soils have low buffering capacity, low water retention and are susceptible to soil erosion and compaction. Thus, soils in this region suffer from multiple nutrient deficiencies, nutrient imbalances and degradation of vital chemical properties (Ogunkunle, 2009). Thus, this research is aimed at investigating rate of decomposition and nutrients release from foliage of five leguminous tree species incorporated into three alfisols.

Materials and Methods

Study AreaThe study was carried out at Bayero University Kano (BUK) located in Kano, the capital city of Kano State, Nigeria. It lies between latitude 11o 58' and 11o 50'N, and between longitude 8o 28' and 8o 46'E.

Collection and Preparation of SamplesThe foliage/leaf of the five legume trees and the three soil types were collected from different locations at the university farm. The collected samples of fresh and dried foliage were pooled together in different containers and oven dried at 65°C, after which samples were milled and sieved with 2mm sieve, and incorporated at the rate of 50g each into 500g of sandy, loamy and clay weighed in different buckets. The buckets were kept in a screen house and watered uniformly at an ambient temperature of 16-33°C for 90 days. Measurement of minerals nutrients released was taken after thirty days each and rate of decomposition and release of macro and micro elements were determined in university soil laboratory.

Laboratory Analysis

The determination of nutrients released in the three soil was carried out on monthly basis in the university soil laboratory using the following methods;

Organic carbon (OC): Walkley black wet oxidation (Walkley and Black 1934).

Total nitrogen (TN): Macro Kjeldahl method (Dupont *et al.,* 2013).

Available phosphorus (AVP) Bray 1 method (Bray and Kurtz 1945).

Cation exchange capacity (CEC): Ammonium acetate saturation method (Chapman, 1965).

Iron (Fe): HCL extraction method (Schugerl *et al.,* 1996; Bart, 2001).

Zinc (Zn): HCL extraction method (Schugerl *et al*., 1996; Bart, 2001).

Magnesium (Mg): Atomic absorption Spectrophotometry method (Bisergaeva and Sirieva 2020).

Sodium (Na): Ammonium acetate saturation method (Thomas, 1982).

Potassium (K): Ammonium acetate saturation method (Thomas, 1982).

Calcium (Ca): Atomic absorption Spectrophotometry method (Bisergaeva and Sirieva 2020).

Experimental Design

The treatment consists of dried foliage of the five leguminous tree species (*Albizia lebbeck*, *Acacia nilotica*, *Dalbergia sissoo*, *Delonix regia* and *Parkia biglobosa*) and a control, and three soil types (clayey loamy and sandy). The dried foliage of the leguminous trees was applied at the rate of 50g per 500g of each soil in separate container resulting in a total of 18 treatment combinations arranged in the screen house in a completely randomized design (CRD) with three replication for a period of ninety days, and watered regularly.

Data Collection and Analysis

Data were collected at thirty days interval from each treatment and subjected to analysis to estimates organic carbon (OC), available Phosphorus, cation exchange capacity, total nitrogen, iron, zinc, calcium, Magnesium, Sodium and Potassium. The data collected were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS, version 9.0), and treatment means were separated using Duncan Multiple Range Test (DMRT) at *P=0.05* level of probability (Steel and Torrie 1960). Correlation analysis was also carried out to determine degree of association among each nutrient variables using Pearson's correlation model.

Results and DiscussionEffect of leguminous tree species on organic carbon, available

phosphorus, total nitrogen and cation exchange capacity in three alfisol soils at BUK

The effect of leguminous trees on organic carbon, available phosphorus, total nitrogen and cation exchange capacity in three alfisol soils is presented in Table 1.

There was significant difference in the amount of OC, AVP, TN and CEC obtained from the five leguminous trees and the control. Significantly higher OC were recorded from *D. sissoo* and *P. biglobosa,* and were significantly different from other leguminous trees that had similar OC content, that were also significantly different from the control with the lowest OC. Organic carbon help buffer soil pH, preventing extreme pH fluctuation (Spurgeon and Dehnel 2016). Similarly, the amount of AVP recorded from the leguminous trees was also significantly (P≤0.05) higher in *D. sissoo* than other species, and this was followed in decreasing order by *A. lebbeck, D. regia, P. biglobosa, A. nilotica* and control having the lowest amount of AVP released, *A. lebbeck* > *D. regia* > *P. biglobosa* > *A. nilotica* > control. However, control treatment recorded highest quantity of Nitrogen than the leguminous trees that had similar amount of nitrogen. Boyer *et al.,* (2002) emphasizes that there is need for proper management of nitrogen in ecosystems in order to mitigate environmental problems such as eutrophication. The CEC from leguminous trees was also significantly higher in *D. sissoo* than other species, followed in decreasing order: *P. biglobosa* > *D. regia* > *A. nilotica* >*A. lebbeck* > control with the least CEC value. Anderson *et al.* (2015) stated that sandy soils with low CEC may benefit from organic matter additions, leading to improved nutrient retention and plant growth.

There was significant difference in the amount of OC, AVP, TN and CEC recorded from the three soils, with loamy soil having significantly highest amount of OC compared to clayey and sandy soils. Similarly, clayey soil recorded higher amount of OC than sandy which had the least quantity. Study has shown that organic matter in loamy soils increases their water-holding capacity (Brady and Weil's 2010). However, the amount of AVP, TN and CEC obtained was significantly higher in clayey soil than sandy and loamy soils. Presence of adequate phosphorus in sandy and clay soils has been noted to be critical for reducing risk of phosphorus runoff into water bodies. This has environmental implications as excessive phosphorus in water can lead to eutrophication (Sharpley *et al.,* 2013), and this can also lead to environmental pollution (Withers *et al.,* 2014). Sandy soil had similar amount of TN compared to clayey with loamy soil resulting in lowest quantity. This implies that management of nitrogen in clay and loam soils maintains soil health and reduce nitrogen-related environmental issues (Galloway *et al.,* 2004). The CEC recoded from loamy soil was significantly different from sandy soil which had the lowest CEC. Higher CEC could be attributed to high accumulation of organic matter which implies more ability to hold cations. Odunze and Kureh (2007) reported that increase in CEC is due to high litter fall. Higher CEC value in clayey and loamy soils have been reported to prevent leaching (Brown and Johnson 2014).

The effect of interaction of leguminous trees and soil types on OC, AVP, TN and CEC were found to be significant as shown in figure I-IV.

D. sissoo and *P. biglobosa* foliages incorporated in loamy soil resulted in significantly higher OC than other treatment combinations, while the lowest value was obtained from the control (no incorporation) in sandy soil (figure I). The amount of AVP obtained from the interaction of leguminous trees and soil types were higher when *D. sissoo* and *D. regia* foliages were incorporated in clayey soil compared to other treatments with the least amount recorded from control in sandy soil (figure II). Addition of *D. regia* foliage in sandy soil resulted in higher amount of total nitrogen while the lowest value was obtained from the same species incorporated in clayey soil (figure III). The highest CEC value was obtained from *P. biglobosa* foliage added to clayey soil while the lowest was recorded from control in sandy soil (figure IV).

Table 1: Effect of leguminous tree species on organic carbon, available phosphorus, total nitrogen and cation exchange capacity in three alfisol soils at BUK in Sudan Savannah Agroecological zone

Treatment	OC (%)	AvP (mg/kg)	TN (%)	CEC (cmol/kg)
Legume tree (L)				
Albizia lebbeck	0.85b	14.39b	0.21b	5.66de
Acacia nilotica	0.80b	9.81e	0.23b	5.81d
Dalbergia sisoo	1.03a	16.35a	0.19b	7.40a
Delonix regia	0.84b	13.37c	0.36b	6.37c
Parkia biglobosa	0.95a	10.21d	0.29b	6.76b
Control	0.56c	8.20f	0.60a	5.37e
SE±	0.029	0.122	0.061	0.111
Soil type (S)				
Clayey	0.66b	12.83a	0.39a	7.48a
Loamy	1.31a	11.40c	0.20b	6.55b
Sandy	0.54c	11.93b	0.34a	4.66c
SE±	0.020	0.086	0.043	0.079
Interaction				
L*S	<.0001**	<.0001**	<.0001**	<.0001**

Means followed by same letter(s) within same column are not different statistically at *P=0.05* level of probability using DMRT **= F-value significant at (P≤0.01) OC = organic carbon AvP = Available phosphorus TN = Total nitrogen CEC = Cation exchange capacity

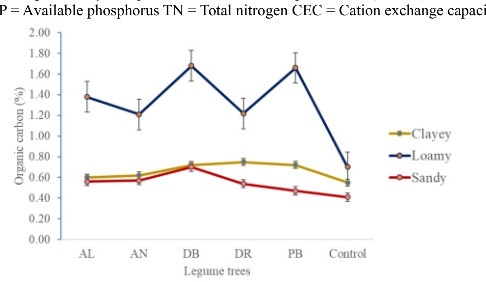


Figure I: Graph showing organic carbon content of the different legume tree species under the three soil types

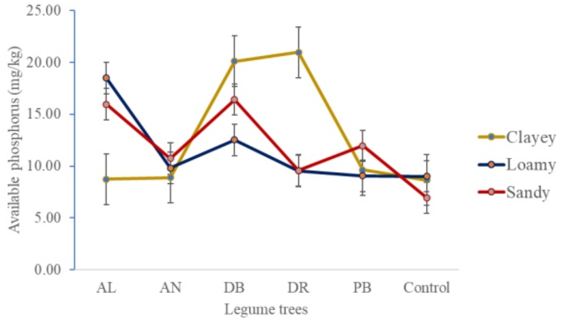


Figure II: Graph showing available phosphorus of the different legume legume tree species under the three soil types

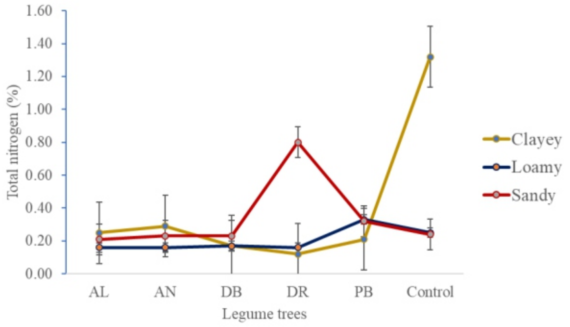


Figure III: Graph showing total nitrogen of the different leguminous tree species under the three soil types

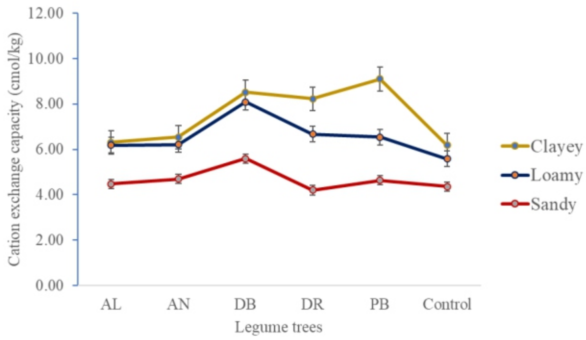


Figure IV: Graph showing cation exchange capacity of the different legume tree species under the three soil types

Effect of leguminous tree species on iron and zinc content in three alfisol soils at BUK

The effect of leguminous trees on iron and zinc content in three alfisol soils is presented in Table 2. There was significant difference in iron and zinc obtained from the leguminous tree species with *D. sissoo* foliage having significantly higher amount of iron and zinc than other species. However, the amount of iron recorded from *A. lebbeck, A. nilotica* and *D. regia* foliages were statistically similar, but significantly different from *P. biglobosa* and the control. Similarly, *P. biglobosa* recorded significantly higher value than control which had lowest amount. Presence of iron in soils have been observed to affect microbial activity serving as an electron acceptor in microbial respiration which influence decomposition of organic matter and nutrient cycling (Sposito, 2008). Likewise, *D. regia* and *P. biglobosa* had similar zinc content significantly different from *A. nilotica, A. lebbeck* and the control, while *A. nilotica* also recorded zinc value that was statistically not at par with *A. lebbeck* and the control. Similar trend was observed with *A. lebbeck* foliage having significantly higher zinc than control that recorded lowest amount. Gupta *et al.,* (2016) postulated that zinc helps plants cope with environmental stresses, enhancing plant resistance to abiotic stressors, such as drought and salinity in sandy, loam and clay soil, it also promotes efficient nutrient uptake (Cakmak and Kutman 2018).

The amount of iron and zinc recorded from the three soil types were significantly different with loamy soil having significantly higher iron and zinc content than clayey and sandy soil, while the iron and zinc obtained from clayey soil was also found to be significantly different from that of sandy soil which recorded the lowest values of the two micro-nutrients It has been reported that oxide of Fe in loam and clay soil stabilize soil structure, prevent compaction and erosion (Feng *et al.,* 2013 and Karathanasis *et al.,* 1988).

There was significant effect of leguminous trees and soil types interaction on the two micro-nutrients recorded (figure V and VI). Addition of *D. sissoo* foliage in loamy soil resulted in significantly higher iron and zinc than other treatment combinations while lowest values of the two micro-nutrients was obtained from the control in clayey and sandy soil respectively.

Table 2: Effect of leguminous tree species on iron and zinc contents in three alfisol soils at BUK in Sudan Savannah Agroecological zone

Treatment	Iron (mg/kg)	Zinc (mg/kg)
Legume tree (L)		
Albizia lebbeck	3.58b	3.47d
Acacia nilotica	3.57b	3.80c
Dalbergia sissoo	4.00a	4.74a
Delonix regia	3.54b	4.20b
Parkia biglobosa	3.05c	4.15b
Control	2.68d	2.63e
SE±	0.117	0.062
Soil type (S)		
Clayey	3.29b	3.74b
Loamy	4.13a	4.35a
Sandy	2.78c	3.40c
SE±	0.082	0.044
Interaction		
L*S	<.0001**	<.0001**

Means followed by same letter(s) within same column are not different statistically at *P=0.05* level of probability using DMRT **= F-value significant at ($P \leq 0.01$)

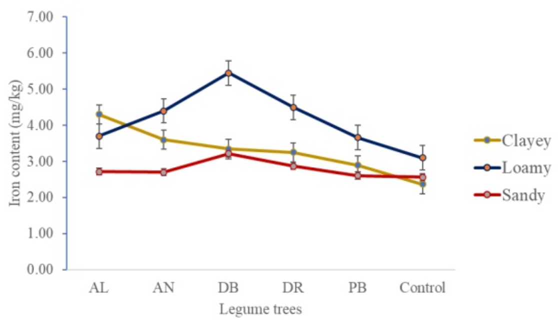
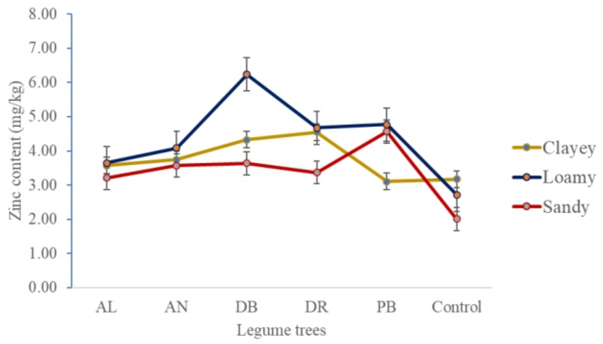


Figure V: Graph showing iron content of the different legume tree species under the three soil types



Effect of leguminous tree species on exchangeable bases (Ca, Mg, Na and K) in three alfisol soils at BUK

The effect of leguminous trees on exchangeable bases (Ca, Mg, Na and K) in three alfisol soils is presented in T~~t~~able 3.
Significantly higher amount of Ca was obtained from *A. nilotica* foliage statistically (P≥0.05). Comparable to *D. regia* and *D. sissoo* but significantly different from *A. lebbeck, P. biglobosa* and control. However, the Ca obtained from *D. regia, D. sissoo* and *P. biglobosa* were not significantly (P≥0.05) different, but were not statistically at par compared to *A. lebbeck* and control that resulted in similar (P≥0.05) Ca content. The amount of Ca obtained from the three soil types were also significantly different with clayey soil having significantly higher amount than loamy soil which also had higher Ca content than sandy that recorded the lowest. Calcium is a cation that competes with other cations like aluminium and iron preventing their toxicity and enhancing availability of essential nutrients, in sandy clay and loam soil (Havlin *et al.,* 2014; Marschner, 2012).
Similarly, *A. nilotica* resulted in significantly higher in amount of Mg compared to *D. sissoo* but significantly different from other leguminous tree species and the control. However, Mg recorded from *D. sissoo* was comparable to *D. regia* and *P. biglobosa* but significantly different from *A. lebbeck* and control. Likewise, Mg obtained from *D. regia* and *P. biglobosa* were similar and at par with *A. lebbeck*, and significantly different from control. There was significant difference in Mg obtained from the three soil type with loamy soil having significantly higher amount than clayey and sandy both of which that were statistically (P≥0.05) at par. Studies have shown that magnesium application enhances crop yields in soils contributing to better nutrient availability and overall plant health, (Sikora and Szatanik-Kloc 2016), and yield leading to increased production (Schwab and Lindsay 2015).
The Na and K obtained from the leguminous tree species was significantly higher in the control than other treatments. Similarly, Na obtained from *A. nilotica* was significantly different from *D. sissoo, D. regia* and *P. biglobosa* that were statistically (P≥0.05) similar. However, no significant (P≥0.05) difference in K obtained from the leguminous trees was observed. Likewise, there was no significant (P≥0.05) difference in Na and K recorded from the three soil types. Sodium levels are extremely high in sandy soil leading to formation of sodic soils, which are characterized by poor structure and reduced fertility while in loam, it leads to salinity problem (Rengasamy, 2010). In clay soil, sodium can disperse clay particles, leading to deflocculation of soil particles by reducing compaction and enhancing water infiltration.

There was significant effect of leguminous trees and soil types interaction on Ca and Mg contents recorded (figure VII and VIII). Application of *A. nilotica* foliage in loamy soil resulted in significantly higher Ca and Mg than other treatment combinations, while lowest values of the two cations was obtained from *A. lebbeck* in sandy soil.

Table 3: Effect of leguminous tree species on rate of exchangeable bases (Ca, Mg, Na and K) in three alfisol soils at BUK in Sudan Savannah Agroecological zone

Treatment	Iron (mg/kg)	Zinc (mg/kg)
Legume tree (L)		
Albizia lebbeck	3.58b	3.47d
Acacia nilotica	3.57b	3.80c
Dalbergia sissoo	4.00a	4.74a
Delonix regia	3.54b	4.20b
Parkia biglobosa	3.05c	4.15b
Control	2.68d	2.63e
SE±	0.117	0.062
Soil type (S)		
Clayey	3.29b	3.74b
Loamy	4.13a	4.35a
Sandy	2.78c	3.40c
SE±	0.082	0.044
Interaction		
L*S	<.0001**	<.0001**

Means followed by same letter(s) within same column are not different statistically at *P=0.05* level of probability using DMRT **= F-value significant at (P≤0.01)

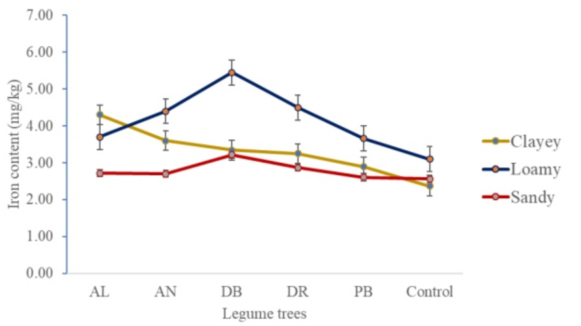
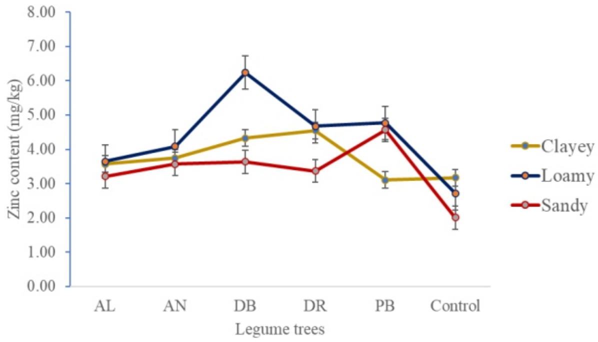


Figure V: Graph showing iron content of the different legume tree species under the three soil types



Correlation Analysis

The correlation coefficients recorded from macro and micro nutrients as influenced by foliage of the leguminous tree species and soil types is presented in Table 4. There was positive and significant correlation between OC and CEC, Fe, Zn, Ca and Mg, while for AvP, it was positively correlated to CEC and Zn. The degree of association observed from CEC in relation to Fe, Zn and Ca was positive and significant, while Fe shows significant and positive correlation to Zn, Ca and Mg. Similarly, Zn shows positive and significant correlation to Ca, while Ca and Mg were positive and significantly correlated. Likewise, significant and positive correlation was observed between Na and K.

However, the degree of association between AvP compared to TN and Mg, TN vs Fe, Zn vs Na, and Ca vs Na were significant and negatively correlated, while no significant correlation was observed between OC compared to AvP, TN, Na and K, AvP vs Fe, Ca, Na and K, CEC vs TN, Mg, Na and K, TN vs Zn, Ca, Mg, Na and K, Fe vs Na and K, Zn vs Mg, Ca vs K, and Mg vs Na and K respectively.

The positive and significant relationship observed between OC and majority of the nutrient variables with correlation coefficient ranging between 0.357** to 0.715** might be due to higher levels of organic matter decomposition resulting in higher levels of organic carbon, microbial activity, improve soil structure, ability to retain water and high humic content

The negative correlation observed among some of the variables is an indication of an increase in one variable with a corresponding decrease in the other, and this corroborates the finding of Jamila (2023) who observed similar negative trend between sand and silt with clay. However, this disagrees with the same report of a positive correlation between AvP and TN which is contrary to the result obtained from this study that showed an increase in AVP with decrease in TN.

Table 4: Correlation matrix of soil chemical parameters as affected by legume tree species in three soil types at BUK in Sudan Savannah Agroecological zone

Var	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	0.086^{NS}	1.000								
3	0.399^{**}	0.320^{*}	1.000							
4	-0.243^{NS}	-0.305^{*}	-0.232^{NS}	1.000						
5	0.715^{**}	0.008^{NS}	0.419^{**}	-0.349^{**}	1.000					
6	0.662^{**}	0.293^{*}	0.458^{**}	-0.204^{NS}	0.641^{**}	1.000				
7	0.408^{**}	0.218^{NS}	0.688^{**}	-0.206^{NS}	0.469^{**}	0.400^{**}	1.000			
8	0.357^{**}	-0.456^{**}	0.042^{NS}	-0.014^{NS}	0.477^{**}	0.200^{NS}	0.280^{*}	1.000		
9	-0.128^{NS}	-0.251^{NS}	-0.247^{NS}	0.077^{NS}	-0.067^{NS}	-0.387^{**}	-0.321^{*}	0.196^{NS}	1.000	
10	-0.060^{NS}	-0.073^{NS}	0.046^{NS}	0.230^{NS}	-0.169^{NS}	-0.112^{NS}	0.022^{NS}	0.046^{NS}	0.289^{*}	1.0000

1 = Organic carbon; 2 = Available phosphorus; 3 = Cation exchange capacity; 4 = Total nitrogen; 5 = Iron; 6 = Zinc; 7 = Calcium; 8 = Magnesium; 9 = Sodium; 10 = Potassium

NS = r-value not significant
*= r-value significant at
**= r-value significant at ($P \leq 0.01$)
N = 54
Df = (N-2) = 52

Conclusion and Recommendation

The result obtained from this study shows significant variation in the rate of decomposition and release of mineral nutrients from leguminous trees foliage in three alfisols. The most active leguminous foliage for decomposition and release of nutrient was found to be highest in *D. sissoo* followed by *P. biglobosa*, *D. regia, A. nilotica* and *A. lebbeck*, while the most active soil in what sense?, expatiate is loamy soil followed by clay with least rate in sandy soil. Since the rate at which mineral nutrients are released occurred at different phases from the leguminous tree species in the three alfisols, it is advisable to farmers willing to practice agro-forestry to critically assess the leguminous tree foliage that would release the most significant mineral nutrients into a particular soil. Similarly, the nutrient demand of crop that will be integrated should be studied together with its life cycle so that the rate of decomposition and release of nutrients would go hand in hand with the crop to be raised.

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