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ASSESSMENT OF NITROGEN MINERALIZATION OF *FAIDHERBIA ALBIDA* AND ITS EFFECT ON MAIZE (*Zea mays* L.) GROWTH ON AN ALFISOL IN SAMARU, NORTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

This study was carried out to assess the effect of nitrogen mineralization of *Faidherbia albida* foliage and urea on maize growth in Samaru, Northern Guinea savanna Alfisols, Nigeria. A maize variety “Sammaz 32” was used as a test crop. The treatments consisted of five *Faidherbia albida* (FA) levels 0, 2, 4, 6 and 8 tons (t) ha^{-1} equivalent to 0, 3.56, 7.12, 10.67 and 14.22g pot^{-1} respectively and four urea fertilizer (0, 30, 60 and 120 kg N ha^{-1} represented as 0, ¼, ½ and FRR (full recommended rates) equivalent to 0, 0.13, 0.23 and 0.46 g pot^{-1} respectively) laid out in a completely randomized design with three replications. Result of the incubation study showed 49.16 of the N immobilized in the urea treatments, while all FA foliage mineralized in 63 days. Four (4 tons ha^{-1} FA gave the highest percentage of net N mineralization of 32.35%, while 8 tons ha^{-1} FA recorded the least net N mineralization percentage of 2.85%. Also, 4 tons ha^{-1} FA had the highest net mineralization rate of 10.55 mg kg^{-1} for NH_4-N and 33.27 mg kg^{-1} for NO_3^-–N with nitrification at 75% over ammonification, suggesting prevention of N loss through volatilization. The combination of 4 tons ha^{-1} FA + 30 kg Nha^{-1}or + 60 kg Nha^{-1}of urea gave the best treatment combinations for enhancing soil fertility though application of 120 kg Nha^{-1} gave the highest N value. Due to the negative impact of N fertilizer such as soil acidity resulting in poor soil quality and low yields, and to reduce production cost (fertilizer input cost) and maximize the profit, the use of 4 tons ha^{-1} FA + 30 kg Nha^{-1} is suggested for maize production in the Northern Guinea savanna of Nigeria.

Keywords: *Faidherbia albida*; nitrogen mineralization; maize; Alfisols

INTRODUCTION

Production of maize under degraded agricultural lands has been of great concern in Northern Guinea savanna (NGS) agro-ecology of Nigeria due to soil acidity and high mineralization rate of organic matter as a result of high soil temperature, seasonal soil moisture conditions (due to high evaporation rate), soil aeration and salt content (electrical conductivity/EC), quality and quantity of organic materials. This has posed a major obstacle to food security and sustainable maize crop production and in turn, affects farmers' livelihood, soil quality and health. Attempts have been made to improve the soils productivity through the combined use of organic amendments that counteracts the negative impact of nitrogen (N) fertilizers such as soil acidity by boosting the soil pH while at the same time enhance soil quality and health (Hamzat, 2022; Yengwe *et al*., 2018; Eche *et al*., 2014, 2013). Some potential biological factors also contributing to low maize yields are low amounts of N transfer and balance in the soil and low N-fixed (Yusuf *et al*., 2009). As reported in several studies, soils of Northern Guinea savanna (NGS) are generally low in soil fertility, such as low organic matter, cation exchange capacity (CEC), total N and phosphorus indicating that the soils have low productivity potentials (Shobayo *et al*., 2018; Eche *et al*., 2014) and mainly dominated by Kaolinitic clay in the clay fraction (Shobayo *et al*., 2018; Jimoh *et al*., 2016). The native soil N is low, and all cereal crops respond to N fertilizer amendments. The soils have been reported to be slightly to moderately acidic in reaction and have moderate P fixation properties (Hamzat, 2022; Carsky *et al*., 1998). Consequently, long-term continuous mono-cropping with inadequate nutrient replenishment would lead to rapid decline in soil productivity due to these low soil physical and chemical properties.

Maize, the most widely cultivated crop has now become more essential in Nigeria (FAO, 1999). It is grown both as food and cash crop. The major problems facing maize production in the region are mainly erratic rainfall and poor soil fertility status. High rate of evaporation (Vanlauwe *et al*., 2001) and erratic rainfall especially in the early growing season (Eche, 2011) has been reported to limit maize yield. Nitrogen (N) is the most limiting nutrient element for maize production especially in this region (Sanginga, 2003). A steady supply of N is needed during the early growth and silking stages which is provided by the action of soil microbes on the soil organic matter (SOM) unless applied through fertilizers. Unfortunately, soils of the NGS of Nigeria may not supply the quantities of N required because the soils are low in N and levels of N decline rapidly once cropping commences (Sanginga *et al*., 2001). Therefore, N supplied from the breakdown of organic matter such as Apple-ring acacia (*Faidherbia albida* "FA") foliage must be supplemented with N from inorganic sources (Eche *et al*., 2014). Also, timely and precise quantity of soil N supply from FA during maize growing season is an essential role in establishing the best N management practice using this organic amendment.

Therefore, considering the gains and benefits derived from organic soil amendments, there is need to carry out research on mineralization efficiency of *Faidherbia albida* (FA) foliage. Reason being that data on adequate successful N mineralized rates would ensure timely and precise quantity of soil N supply from FA during maize growing season and this is an important role in establishing the best N management practice using this organic amendment. Little or no work has been done regarding N mineralization of FA foliage on maize growth in an Alfisols being the dominant soil type in the NGS region of Nigeria. Therefore, this study was designed to assess the N mineralization effects on maize growth and development in an Alfisols of NGS region of Nigeria.

MATERIALS AND METHODS

Study Area and Experimental Soil

Screen house study was conducted at the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria (11o9′ N, 7o36′E) to determine the potential of Apple-ring tree to improve soil properties and evaluated for 3 months. Soils of the study area is classified as Typic Haplustalf according to USDA Soil Taxonomy system

(Ogunwole *et al.,* 2001). The soil for the experiment was collected from S1 field of Institute for Agricultural Research (IAR) farm, Samaru, Zaria in the Northern Guinea savanna with the coordinates: Latitude 11°25′20″ N Longitude 7°08′30″E (Yusuf and Yusuf, 2008). Four 4kg of sieved soil was thoroughly mixed with appropriate rates of grounded Apple Ring foliage into plastic pots of about 5- liter capacity and incubated for nine weeks. The pots were placed on plastic receivers and water maintained at pot capacity (freely drained for three days after thorough watering) and any seepage collected on the plastic receivers was returned to the pot. This was achieved by weighing the pots with the soil before and after the soil was saturated and left for three (3) days to drain. The difference between the non - saturated and saturated soil was the amount of water applied.

Leaves and Stalks of Apple Ring Sampling and Tissue Analysis

Matured leaves and stalks of Apple ring were collected fresh from the tree at National Animal Production and Research Institute (NAPRI), Shika. It was air dried and ground to pass through 2 mm sieve. The ground samples were analyzed to determine its nutrient composition and maize leaves index was determined by the micro-Kjeldahl wet digestion method (Bremner, 1996). Plant tissue samples were digested in sulphuric acid and analyzed for total P by the molybdo-phosphoric yellow colour method; cations (Ca and Mg) determined using AAS, while Na and K by flame photometry (Okalebo *et al.*, 2002). Organic matter and ash content using ash method (Anderson and Ingram, 1993).

Experimental Design and Treatments

The experiment was laid out in completely randomized design (CRD) and the treatments consisted of 5 rates of apple-ring (*Faidherbia albida*) (0, 3.56, 7.12, 10.67 and 14.22g equivalent to 0, 2, 4, 6- and 8-tons FA ha^{-1}) foliage and four rates of N (urea) (0, 30, 60 and 120 kg N ha^{-1} represented as 0, ¼, ½, and FRR (control, quarter, half and full recommended rates per hectare) equivalent to 0, 0.13, 0.23 and 0.46 g pot-1). Both phosphorus (P) and potassium (K) fertilizers were applied at the 60 kg ha^{-1} optimum recommended rate. The treatment combinations were replicated three times, giving a total number of 60 pots.

Soil Sampling and Laboratory Analysis

The soil samples were taken from the topsoil (0-15cm) of the field. The samples were air-dried crushed and sieved through 2mm mesh sieve and subsampled for soil physical and chemical properties using standard methods reported by Anderson and Ingram (1993). Soil samples collected before and after the decomposition studies were analyzed for various parameters such as particle size distribution estimation by the hydrometer method of Gee and Dr. (2002), soil pH in 1: 2.5 soil water ratio in 0.01M $CaCl_2$ suspension with the glass electrode pH meter; and exchangeable bases by extraction with neutral 1N NH_4OAc using the method of Okalebo *et al.* (2002). Sodium (Na) and K were extracted, with flame photometer while Ca and Mg using atomic absorption spectrophotometer (Kundsen *et al.,* 1982). The cation exchange capacity (CEC) by the ammonium saturation method, followed by distillation (Okalebo *et al.,* 2002). Organic carbon by the Walkley and Black wet oxidation method according to Okalebo *et al.* (2002) total N using Kjeldahl procedure (Bremner and

Mulvaney, 1982), available P by the Bray 1 method according to Okalebo *et al.* (2002). Micronutrients (Zn, Cu, Fe, Mn) were determined using 1 % EDTA and the concentrations of these elements was determined using AAS (Okalebo *et al.*, 2002). The net mineralization index was calculated using the formula below:

N mineralization (%) = 100 x (Mineral-Ninput – Mineral-Ncontrol)/N added

Where:

Mineral-Ninput = simulated ammonium- + nitrate-N in systems with the added source.
Mineral-Ncontrol = the absence of any input (Probert *et al.*, 2005; Nourbakhsh and Dick, 2005).

Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) using SPSS computer statistical package version 23 (SPSS, 2015). When F-values were significant, treatment means were compared using Duncan multiple range test (DMRT) at 5% level of significance (Duncan, 1955).

RESULTS AND DISCUSSION

Soil Characteristics of the Study Site

Results of the soil properties of the experimental soil before establishment of studies in 2017 are presented in Table 1. The soil was sandy loam in texture and low in clay content. It was slightly acidic, with pH value in $CaCl_2$ solution lower than pH in water suggesting the soil possesses a net negative charge in the colloidal complex (Daudu, 2004). The pH value in water was above 6.0 suggesting exchangeable Al toxicity would not be a problem in this soil. The total soil nitrogen is high (4.00g kg^{-1}) while available P content is medium (10.43 mg kg^{-1}). The soil was characteristically low in organic carbon content (4.41 g kg^{-1}) Chude *et al.*, 2012) (Table 1). The soil was characteristically low in organic carbon content (4.41 g kg^{-1}). Given the high mineralization rate in the Northern Guinea savanna ecology, carbon stock in the soil could be low. The products of mineralization which would include some organic acids will reduce the pH and increase available N while reducing total C in the soil. Also, mineralization results in the production of CO_2 which in turn would affect the C level in soil leading to low OC content. The low total soil organic carbon coupled with the associated sandy loam texture, would encourage rapid leaching of cations (Odunze, 2006), resulting in low cation exchange capacity. Exchangeable bases were generally low in the soil. Calcium (2.67 cmol kg^{-1}) and magnesium (0.65 cmol kg^{-1}) were however the dominant cations on the soil exchange sites. The effective cation exchange capacity (ECEC) of the soil was low (3.95 cmol kg^{-1}) suggesting that the soil could be susceptible to soil acidification because the ability to hold on the basic cations is low. The low soil nutrients content obtained shows the possibility of a good response to applied nutrients, which is an important criterion in selection of the experimental soil. Micronutrients were at safe level since the values did not reach toxic level of 50.0 mg kg^{-1} in the soil (FAO, 2008).

Table 1: Physical and chemical characteristics of soils used in the Screen house

Soil property	Amount in soil	Grade
Particle sizes (g kg^{-1})		
Clay	153	Low
Silt	387	Medium
Sand	460	High
Textural class	Sandy Loam	
pH (H_2O; 1:2.5 w/v)	6.81	Neutral
pH (0.01M $CaCl_2$; 2.5 w/v)	5.69	Slightly low
Bray-1 P (mg kg^{-1})	10.43	Medium
Organic Carbon (g kg^{-1})	4.41	Low
Total N (g kg^{-1})	4.00	High
Exchangeable cations (cmol kg^{-1})		
K	0.23	Medium
Ca	2.67	Medium
Mg	0.65	High
Na	0.19	Low
Total Exchangeable base (TEB)	3.74	Low
Cation exchange capacity (CEC)	5.20	Low
Effective cation exchange capacity (ECEC)	3.95	Low
Exchangeable Acidity (EA)	0.21	Low
Extractable micronutrients (mg kg^{-1})		
Zn	6.20	Medium
Fe	23.27	High
Cu	2.50	Medium
Mn	3.46	Medium

Note: *ECEC = TEB + EA

Characteristic properties of the *Faidherbia albida* Foliage Used for the Study

Although, all nutrients in the soil organic matter may not be available to a crop, but information obtained can give a qualitative estimate of the organic material (Palm *et al.*, 1997). The characteristic properties of the apple-ring tree used in the study showed that OC (428.3 g kg^{-1}), N (29.8 g kg^{-1}) and K at (37.5 g kg^{-1}) (Table 2) were high while P being at l.94 g kg^{-1} was moderate. The C: N ratio is 14.1 which is less than 30:1, indicating a fast decomposition rate resulting in a net release of these nutrients on application to the soil. This agrees with the findings of Eche (2011) and Adeboye *et al.*, 2006) who observed higher nutrient release due rapid decomposition rate as a result of C: N ratio below 30:1, though direct incorporation of FA foliage into soil before planting is expected to give better results in terms of enhancing nutrients release and subsequent uptake by the crop (Murwira and Kirchmann, 1993; Palm *et al.*, 2001). The lignin, cellulose, hemicellulose and total phenol concentration are: 210, 198, 114 and 12.1 g kg^{-1} respectively were within safe limits and showed that the lignin + polyphenol: N ratio is less than 10 which is an index for predictor of N mineralization (Fox *et al.*, 1990).

Table 2: Characteristics of the *Faidherbia albida* used in the study

Parameter	g kg^{-1}
N	29.8
OC	428.3
K	37.5
Ca	17.1
Mg	2.2
Lignin	210
Cellulose	198
Hemicellulose	114
Total phenol	12.1
C: N	14: 1
N: P	15: 1
C: P	221: 1

Mineralization of Nitrogen

Results of the screen house mineralization studies are presented in Table 3. Result of the effect of urea treatment on Ammonium-N (NH_4^+-N) and Nitrate-N (NO_3^- -N) showed no significant difference among the treatments throughout the incubation periods except at 9 weeks for Nitrate-N (NO_3^- -N) with the control having the highest amount of net mineralized Nitrate-N (NO_3^- -N). This could have been due to immobilization of Ammonium-N (NH_4^+-N) and Nitrate-N (NO_3^- -N) by microbes (though immobilization was not estimated). This agrees with the findings of Mohammed, (2013) and Martin and Louise, (2003) who observed immobilization in NPK fertilizer treatments, suggesting that low input of organic matter using urea supported more active microbial biomass with greater N demand resulting in nitrogen immobilization. In the case of FA treatment, there was no significant difference at 6-week incubation period on NH_4^+-N, whereas at 3 and 9-week incubation periods there was significant difference on amount of NO_3^- -N mineralized.

The highest release of Ammonium (NH_4^+-N) and Nitrate-N (NO_3^- -N) was recorded from 4 FA at 3 and 9-weeks for NH_4^+-N (3.78 mg kg^{-1} and 3.47 mg kg-^{1}) and at 3 and 6 weeks for NO_3^- -N (12.48 and 11.75) (Table 3), then followed by 2FA treatment for both Ammonium (NH_4^+-N) and Nitrate-N (NO_3^- -N) at the same incubation periods. The lowest values of Ammonium (NH_4^+-N) and Nitrate-N (NO_3^- -N) were recorded with the application of 8 tons FA ha^{-1}. This relatively low N mineralization in 8 FA treatment could be due to the higher organic carbon content resulting in more microbial biomass with high N demand. The treatment with 4FA gave generally the highest values for both NO_3^--N and NH_4^+ -N compared to other treatments showing that at 4tonsha-^{1} application of FA could be the optimum nutrient level required by microorganisms before mineralization (nutrient release to plants). This reflected in the cumulative N mineralized at 43.62 mg kg-^{1}, compared to other treatments (Table 3).

There was more release of NO_3^--N compared to NH_4^+-N indicating the presence of heterotrophic microbes that take up NO_3^- -N than NH_4^+-N (Martin and Louise, 2002). There was no significant different in the interaction between FA and urea.

Table 3: Effect of mineralization of *Faidherbia albida* and urea for 9 weeks in the screen house

Treatment	(mg kg^{-1})							
	NH_4^+-N				NO_3^--N			
Urea N kg ha^{-1}(N)	3	6	9	Net min. NH_4^+-N	3	6	9	Net min. NO_3^--N
0	3.23	2.98	3.28	9.49	10.27	8.10	10.13a	28.50
¼ RR	3.23	2.94	2.90	9.07	9.69	8.68	8.68ab	27.05
½ RR	3.15	3.07	2.81	9.03	10.27	9.26	7.23b	26.76
FRR	3.65	2.77	3.07	9.49	10.85	9.55	7.81b	28.21
SE ±	0.225	0.249	0.275		0.932	1.000	0.766	
Faidherbia albida tha^{-1} (FA)								
0 FA	2.63b	3.10	2.94ab	8.67	9.58	8.32b	7.41	25.31
2 FA	3.68a	3.10	3.41ab	10.19	9.77	8.14b	10.31	28.22
4 FA	3.78a	3.10	3.47a	10.35	12.48	11.75a	9.04	33.27
6 FA	3.31ab	2.73	2.78ab	8.82	10.31	8.50b	7.96	26.77
8 FA	3.20ab	2.68	2.47b	8.35	9.22	7.78b	7.78	24.78
SE ±	0.252	0.279	0.307		1.042	1.118	0.856	
Interaction								
N x FA	NS	NS	NS		NS	NS	NS	

NS= not significant at 5% level of significance; FA = 0, 2, 4, 6 and 8 tons (equivalent levels per hectare of *Faidherbia albida*; 0-, ¼-, ½- and FRR = 0, ¼, ½ and full recommended rate of N. Net min= Net mineralization.

Effect of *Faidherbia albida* and Urea Fertilizer on Maize Performance

The effects of *Faidherbia albida* (FA) and urea on maize number of leaves, shoot, root and total dry matter weight, stem girth and plant height are shown in Table 4. The application of FA had significant ($p<0.05$) positive effects on the growth parameters. Result also showed that the application of urea had significant ($p<0.05$) positive effect on the number of leaves, stem girth and plant height while no significant effect was obtained for shoot, root and total dry matter weight. There was no significant interactive effect between FA and urea on the performance of maize crop.

Number of leaves

In the sole urea treatment, 60kgNha^{-1} recorded the lowest number of leaves (6.53), though not significantly different from 120kgNha^{-1} with (6.80) while 30kgNha^{-1} recorded the highest (7.53) and not statistically different from the control (7.00). This could be due to the negative impact of nitrogen fertilizer to the soil resulting to soil degradation and nutrient imbalance. In the sole FA treatments, 2 and 8tonsha^{-1} FA had the highest and equal number of leaves (7.25) though not significantly ($p>0.05$) different from the control (7.08) suggesting soil nutrient improvement due to increase in soil pH (Table 1). There was no significant interaction between FA and urea fertilizer.

Stem girth

For the stem girth 30kgNha^{-1} had the highest (2.73 cm) followed by the control (2.62 cm) while 60kgNha^{-1} had the least (2.37cm). In the sole FA treatment, 2 FA recorded the highest (2.71 cm) followed by 8FA (2.64 cm) then the control (2.56 cm) though not statistically ($p>0.05$) different while 4tonsha^{-1} FA had the least (2.35cm) but was not statistically different from 6tonsha^{-1} FA (2.41cm). Result showed no significant interactive effect between FA and urea (Table 4).

Plant height

In the urea treated pots, 120kgNha^{-1} gave the highest plant height (23.55 cm), followed by 30kgNha^{-1} (22.92 cm) though not statistically ($p>0.05$) different indicating the benefit of nitrogen, a major limiting nutrient in maize crop production. Similar trend was observed in the FA treatments with 8tonsha^{-1} FA having the highest plant height (23.73 cm), followed by 2tonsha^{-1} FA (23.24cm). This could be attributed to the release of inorganic N due to rapid decomposition by the action of soil microorganism resulting in the build-up and uptake of available N in the soil. The least plant height was recorded at 4tonsha^{-1} FA and control. Also, there was no interactive effect between FA and urea (Table 4).

Dry matter weight (Shoot, Root and Total dry matter)

Result (Table 4) showed that, shoot, root and total dry matter weights were not significantly different ($p>0.05$) in urea treatment but were significantly ($p< 0.05$) different in the FA treatment. However, shoot, root and total dry matter weights generally increased with increasing rates of urea application but decreased with the application of120kgNha^{-1}. The increase in dry matter weight with increase in application of urea led to the supply of the required nitrogen needed for further growth and development of the maize crop. This is because small starter doses of N fertilizer applied has been reported to meet the plants requirement for N during any N-hunger period especially for maize that is a heavy N-feeder (Chinke, 1999). In the FA treatment, the control gave the highest shoot (8.11g), root (7.78g) and total (15.89g) dry matter weights followed closely by 8tonsha^{-1} FA (7.41g, 7.25g, 14.65g respectively) and then 2tonsha^{-1} FA (6.97g, 7.39g, 14.36g respectively), while 4tonsha^{-1} FA gave the least (4.37g, 3.81g, 8.18g respectively). Result obtained showed that the native soil N level was adequate enough to meet the plant requirement for growth establishment. When the rate of FA was increased, the activity of the microbes may have been overwhelmed or exceeded, hence the microbes were no longer releasing N relative to what is added. They were only consuming and further depress the availability of N in the soil. This is because increase in organic matter will result in increased microbial population and activity due to addition of fresh organic soil amendments. Hence, at 4tonsha^{-1} FA application, the optimum had been attained in immobilization and the microbes start releasing the extra for plant use, thereby resulting in the growth and development of the entire maize plant, as shown in the results obtained for 8tonsha^{-1} FA rate. Results showed no significant ($p< 0.05$) interaction between FA and urea on maize performance.

Table 4: Effect of *Faidherbia albida* and urea fertilizer on maize performance in the screen house

Treatment	Number of Leaves	Stem girth (cm)	Plant height (cm)	Shoot weight <-------	Root weight Yield --(g/pot) --	Total Dry Matter→
			Urea kg N ha^{-1} (N)			
0	7.00a	2.62a	19.78c	6.48	6.54	13.02
¼ RR	7.53a	2.73a	22.92ab	6.91	6.73	13.64
½ RR	6.53b	2.37b	21.43bc	6.78	7.10	13.90
FRR	6.80ab	2.42b	23.55a	6.54	6.33	12.87
SE ±	0.316	0.075	0.885	0.685	0.692	1.020
			Faidherbia albida tha^{-1} (FA)			
0 FA	7.08a	2.56ab	20.71c	8.11a	7.78a	15.89a
2 FA	7.25a	2.71a	23.24ab	6.97ab	7.39a	14.36a
4 FA	6.33b	2.35c	20.23c	4.37c	3.81b	8.18b
6 FA	6.92ab	2.41bc	21.68bc	6.52b	7.15a	13.67a
8 FA	7.25a	2.64a	23.73a	7.41ab	7.25a	14.65a
SE±	0.354	0.084	0.990	0.766	0.773	1.141
Interaction (N × FA)	NS	NS	NS	NS	NS	NS

Note: RR= recommended rate FRR=Full fertilizer recommendation rate, FA = *Faidherbia albida*, NS= Not significant at 5% probability level, SE ± = standard error. Means follows with the same letter in same column are not significantly difference at 0.05 level of probability

Effect of *Faidherbia albida* and Urea on Nutrient Concentration in Maize

Nitrogen

From the results presented in Table 5, there was significant difference in N concentration of Maize tissue in all treatments. In the Urea treatment, the control had the highest N concentration (23.25 g kg^{-1}), though not significantly different from 60kgNha^{-1} (23.19 g kg^{-1}), while the 30kgNha^{-1} (21.95 g kg^{-1}) had the lowest N concentration. The low concentration of N in the 30kgNha^{-1} could be that small starter doses of N fertilizer applied met the needs of the microorganisms during this period of N-hunger. Further increases in application of urea led to the supply of the reduced N needed for further growth, hence the higher values obtained with increase in urea application.

Similar trend was observed under FA treatment. The control had the highest N concentration (24.34 g kg^{-1}) though not significantly (p>0.05) different from 2tonsha^{-1} FA (24.30 g kg^{-1}) and then progressively decreased with 8tonsha^{-1} FA having the lowest N concentration (18.79 g kg). This could be attributed to the fact that it takes longer time to decompose large amount of added organic matter compared to smaller amounts resulting in the faster/ rapid release of nutrients with smaller quantities of organic matter added than when larger amounts are added.

Phosphorus

The results of P concentration of maize tissue showed a general decrease in concentration of P in all treatments indicating that both the soil and FA foliage have very low

P content which invariably resulted in the low concentrations of P in the maize plant tissues. In the case with urea treatment, there was increase in P concentration with increase in urea application with120kgNha^{-1} recording the highest P concentration of 1.36 g kg^{-1}. This could be due to the fact that P is not mobile in soil as N hence, it tends to accumulate with higher application doses.

In the FA treatment, P concentration decreased with with increase in FA foliage with 8tonsha^{-1} FA recording the lowest P concentration of 0.98 g kg^{-1}. This could be due to the numerous loads of heterotrophic microorganisms in soil as a result of increase in FA tree foliage, as opined by Weil and Magdoff (2004), however, causing it to immobilize the available P in the soil leading to competition between plant and microbes. Therefore, resulting to inadequate P uptake by the maize plant.

Potassium

The results of Potassium (K) concentration are given in Table 5. There were generally high K concentrations in Maize tissue from both treatments. The K concentrations decreased with increase in both sole urea and FA foliage applications.

Table 5: Effects of *Faidherbia albida* and urea on nutrient concentrations of maize tissue in the screen house

Treatment	Concentration (g kg^{-1})		
	N	P	K
	Urea kg ha^{-1} (N)		
0	23.25a	1.02c	47.07c
¼ RR	21.95c	1.05ab	50.27b
½ RR	23.19a	1.09ab	59.75a
FRR	22.84b	1.36a	43.98d
SE ±	0.156	0.016	0.081
	Faidherbia albida t ha^{-1} (FA)		
0FA	24.34a	1.08c	51.86b
2 FA	24.30a	1.41a	57.96a
4 FA	23.21b	1.15b	48.37c
6 FA	23.40b	1.02d	45.73e
8 FA	18.79c	0.98e	47.42d
SE ±	0.174	0.018	0.090
Interaction (N × FA)	**	**	**

N. B. * = significant at 0.05 level of probability; **= highly significant at 0.01 level of probability statistically significant using DMRT; RR= recommended rate, FRR=Full fertilizer recommendation rate; FA = *Faidherbia albida*

The highest K concentrations were recorded at 60kgNha^{-1}at (59.75 g kg^{-1}) urea and 2tonsha^{-1} FA (57.96 g kg^{-1}) while the lowest K concentrations in both urea and FA foliage treatments were 43.98 g kg^{-1} and 45.73 g kg^{-1} recorded from 120kgNha^{-1} and 6tonsha^{-1} FA respectively. The generally high K concentrations could have come from the presence of basal application of K as K_2O at 60 kg ha^{-1} in addition to the soil potassium, leading to the high K concentrations in the maize. The FA also contains high concentration of K as showed in Table 2, thereby causing an increase in K concentration.

On the other hand, it shows that the FA foliage is high in K content and enhanced the K concentration in the Maize tissue upon uptake as K is required by maize for stalk strength improvement and root proliferation to avoid lodging, indicating that maize is also a heavy feeder of potassium.

Interaction of *Faidherbia albida* and Urea on NPK Concentration in Maize Tissue

Nitrogen

Figure 1 show the result of interaction of Apple-ring tree and urea on nitrogen concentration in maize tissue. The 2tonsha^{-1}FA + 120kgNha^{-1} recorded highest nitrogen concentration of 31.00 g kg^{-1} in maize tissue while 8tonsha^{-1} FA + 60kgNha^{-1} recorded the least 15.75 g kg^{-1}. This shows the positive interaction of combined application of FA foliage and urea on soil fertility improvement which in turn will enhance maize plant mineral composition. This agrees with the findings of Yengwe *et al*., 2018, Garba (2010) and Murwira and Kirchmann (1993) who observed improvement in soil fertility using combined application of organic matter and inorganic fertilizer, resulting in enhanced nutrient released for subsequent crop uptake.

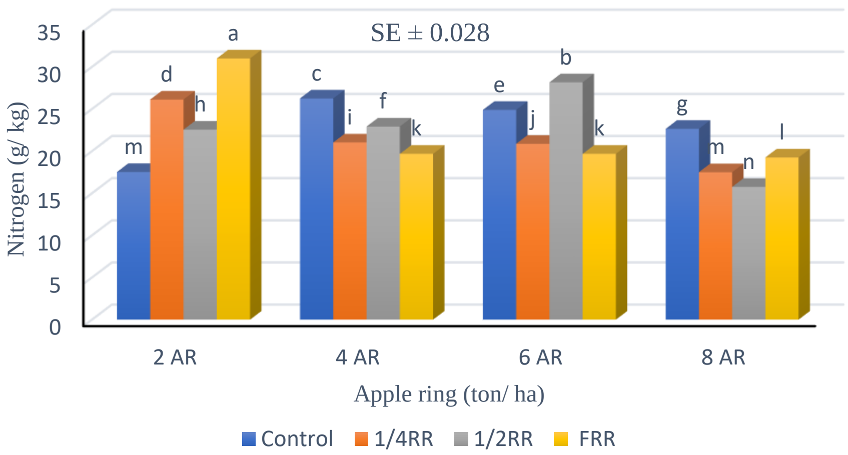

Fig 1: Interaction of *Faidherbia albida* and urea on nitrogen concentration in maize tissue

Phosphorus

From Figure 2, the 2tonsha^{-1} FA + 120kgNha^{-1} recorded highest phosphorus concentration of 2.09 g kg^{-1} in maize tissue while (control) 8tonsha^{-1}FA recorded the least 0.83 g kg^{-1}. The 6tonsha^{-1} FA + 120kgNha^{-1}, 8tonsha^{-1} FA + 30kgNha^{-1} and 8tonsha^{-1} FA +60kgNha^{-1} recorded 0.95, 0.99 and 0.99 g kg^{-1} respectively and were statistically the same. The P concentrations were generally low indicating the low P content in both the urea and FA foliage resulting in rapid rate of immobilization by microorganisms to satisfy their own needs. Hence, uptake by microorganisms led to the depletion of P in the soil and remain little or none for plant uptake.

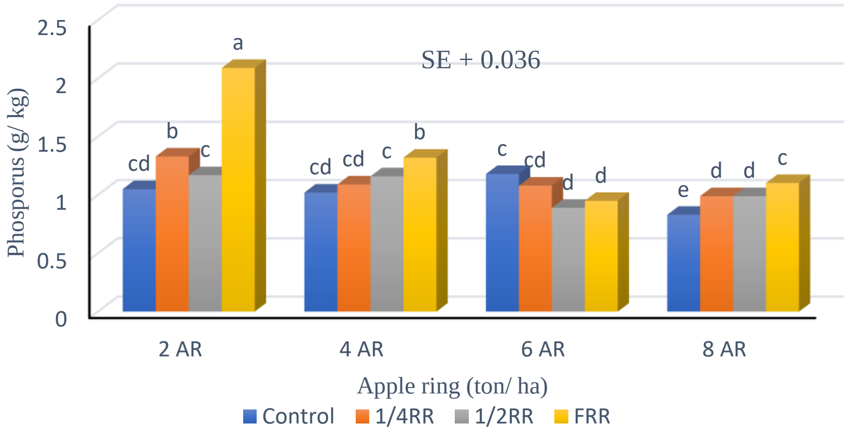

Fig 2: Interaction of *Faidherbia albida* and urea on phosphorus concentration in maize tissue

Potassium

Figure 3 showed that 2tonsha^{-1}FA + 60kgNha^{-1}½ RR recorded highest mean potassium concentration of 83.80 g kg^{-1} in maize tissue while 6tons ha^{-1} FA + 120kgNha^{-1}FRR recorded the least (36.50 g kg^{-1}). Increase in the levels of K concentration in FA may suggest that K may have been well supplied in the soil through mineralization of FA tree foliage and likewise from the basal application of K_2O fertilizer in the soil. Therefore, the maize plant may require a reduced or half of the recommended rate may be sufficient.

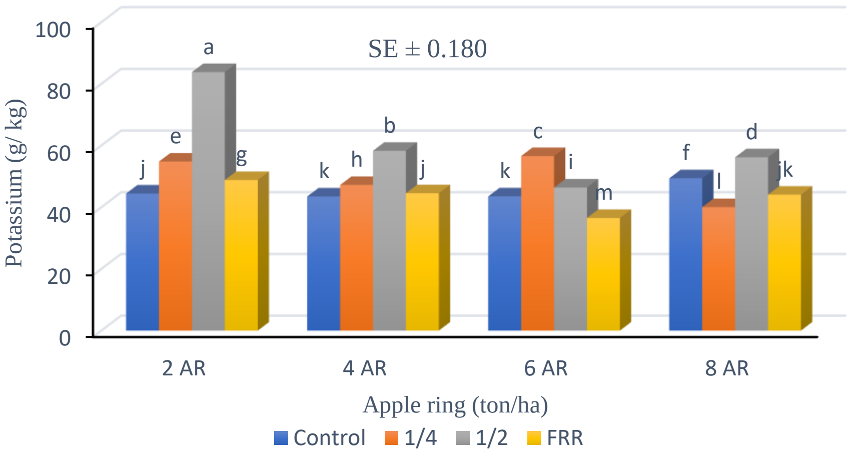

Fig 3. Interaction of *Faidherbia albida* and urea on potassium concentration in maize tissue

CONCLUSION

The C: N ratio of the FA tree foliage was found to be low indicating its high potential for improving and sustaining soil fertility and productivity even under long term crop production. However, the best results were obtained when FA was combined with urea at the rate of 4 tonsha^{-1} FA ha^{-1} + 30kgNha^{-1}, 60kgNha^{-1} or 120kgNha^{-1} which improved N level.

The incubation study showed net N immobilization in the urea treatments. About 49.16 % of the total N applied as FA was mineralized within 63 days' period of incubation and 4ton ha^{-1} FA had the highest percentage of net N mineralization (32.35%) while 8tonsha^{-1} FA gave the least net N mineralization of 2.85%. Also, 4ton ha^{-1} FA gave the highest NH_4-N and NO_3^--N mineralized (10.55 mg kg^{-1} and 33.27 mg kg^{-1} respectively with nitrification at 75% over ammonification, suggesting prevention of N loss through volatilization. Complementary use of FA and urea at 2 FA + 120kgNha^{-1} enhanced N and P concentration in the maize tissue (31.00 g kg^{-1}, but 2 tons ha^{-1} FA + 60kgNha^{-1} improved K concentration. The use of 4 tons FA ha^{-1} + 30, 60, or 120kgNha^{-1} are possible treatment combinations but the use of 4 tons FA ha^{-1} + 30kgNha^{-1} is suggested for maize production in the Northern Guinea savanna of Nigeria to reduce production cost (fertilizer input cost), maximize profit and reduce the problem of soil acidity caused by N fertilizers such as soil degradation, poor soil quality and low yields.

REFERENCES

Adeboye, M.K.A., Iwuafor, E.N.O. and Agbenin, J.O. (2006). The effects of crop rotation and nitrogen fertilization on soil chemical and microbial properties in a Guinea savanna Alfisol of Nigeria. *Plant and Soil*, 281: 97-107. doi:10.1007/s11104-005-3828-5.

Anderson, J.M. and Ingram, S.J. (1993). Tropical biology and fertility: A handbook of methods. England, Wallingford: CAB International.

Bremner, J.M. (1996). Nitrogen-total. *In*: D.L. Sparks (Ed). *Methods of Chemical Analysis, Part3-Chemical Methods*. American Society of Agronomy. Madison, Wisconsin, USA. p. 1085-1121.

Bremner, J.M. and Mulvaney, C.S. (1982). Nitrogen-total. *In*: Page A.L., Miller, R.S. Keeney, D.R. (Eds). *Methods of Soil Analysis, Part II. Chemical and Microbiological Properties*. Soil Sci. Society of America. Society of Agronomy Madison. Wisconsin. Pp. 643-698.

Carsky, R.J., Tarawali, S.A., Becker, M., Chikoye, D., Tian, G and Sanginga, N. (1998). *Mucuna-Herbaceous Cover Legume with Multiple Uses*. IITA, Res. Monogr. 25 Int. Inst. Of Trop. Agric. Ibadan, Nigeria.

Chinke, N.M. (1999). Competition for Nodule sites by Cowpea B*radyrh1zobium* and Parasitic Flowering Plants as affected by Inoculation, N, P and Mo. Msc Thesis Submitted to the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria. 149 pp.

Chude, V.O., Olayiwola, S.O., Osho, A.O. and Daudu, C.K. (2012). *Fertilizer Use and Management Practices for Crops in Nigeria.* 4th Edition. Federal Ministry of Agriculture and Water Resources, Abuja. Pp. 229.

Daudu, C. K. (2004). An evaluation of different sources of organic matter on the fertility and productivity of an Alfisol in the Nigerian savanna. Ph.D. Thesis. Department of Soil Science, ABU, Zaria Nigeria.

Duncan, D.B. (1955). Multiple range and multiple tests. *Biometrics*, 11:1-42.

Eche, N.M. (2011). Soil properties affecting maize yield decline under long-term application of organic and inorganic fertilizers. Ph.D. Thesis, Department of soil science, Faculty of Agriculture, Ahmadu Bello University, Samaru, Zaria. 230pp.

Eche, N.M., Iwuafor, E.N.O., Amapu, I.Y. and Bruns, M.V. (2013). Effect of application of organic and mineral soil amendments in a continuous cropping system for 10 years on chemical and physical properties of an Alfisol in Northern Guinea Savanna Zone. *International Journal of Agricultural Policy and Research*, 1: 116 - 123.

Eche, N.M., Amapu, I.Y., Bruns, M.V., Odunze, A.C. and Uyovbisere, E. (2014). Fertility management effects on soil physical and chemical properties under long-term maize cropping in an Alfisol in Northern Guinea Savanna zone of Nigeria. *Nigerian Journal of Soil Science*, 24 (1): 134 – 146.

FAO (2008). Guide to laboratory establishment for plant nutrient analysis. Food and Agriculture Organization of the United Nation. *Fertilizer and Plant Nutrition Bulletin* No. 19 Rome.

FAO (1999). FAOSTAT Agriculture data, http://apps.fao.org/cgi-bin/nphdb.pl? subset=agriculture. Food and Agriculture Organization of the United Nation, Rome, Italy.

Fox, T.R., Comerford, N.B. and McFee, W.W. (1990). Phosphorus and aluminum release from a spodic horizon mediated by organic acids. *Soil Sci. Soc. Am. J.*, 54:1763-1767.

Garba, J. (2010). Effect of Neem Seed Cake and Inorganic Fertilizer on Soil Fertility and Productivity of Maize in a Savanna Alfisol. M.Sc. Thesis. Dept. Soil Sci., Ahmadu Bello University, Zaria.

Gee, G.W. and Dr, D. (2002). Particle size analysis. *In*: Dane J.H., and Topp G.C. (Eds). *Method of Soil Analysis, Part 4, Physical Methods*. ASA and SSSA Madison, WI., Pp:255-293.

Hamzat, S. (2022). Evaluation of Nitrogen Mineralization of Apple Ring (*Faidherbia albida*) Foliage and its Effect on Soil Properties and Growth of Maize in a Savanna Alfisols of Nigeria. Department of Soil Science. MSc. Dissertation, Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University Zaria. 95pp.

Jimoh, A.I., Malgwi, W.B., Aliyu, J. and Shobayo, A.B. (2016). Characterization, classification and agricultural potentials of soils of Gabari District, Zaria, Northern Guinea Savanna Zone, Nigeria. *Biological and Environmental Science Journal for the Tropics* (BEST), 13 (2): 102 - 113.

Kundsen, D., Peterson, G.A. and Prett, P.F. (1982). Lithium, Sodium and magnesium. *In*: *Methods of Soil Analysis (A.L. page ed) Part II*. American Society of Agronomy: Inc. Madison, Wisconsin. *Agronomy*, 9: 225-246.

Martin, B. and Louise, E. J. (2003). Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems. Department of Vegetable Crops, University of California, One Shields Ave. Davis, CA 95616, USA. *Soil Biology & Biochemistry*, 35: 29–36.

Murwira, H.K. and Kirchmann, H. (1993). Nitrogen dynamics and maize growth in a Zimbabwean sandy soil under manure fertilization. *Commun. Soil Sci. Plant Anal.* 24 (17-18): 2343-2359.

Nourbakhsh, F. and Dick, R.P. (2005). Net mineralization or immobilization potential in a residue-amended calcareous soil. *Arid Land Research and Management*, 19 (4): 299 – 306. Doi: 10.1080/15324980500299615

Odunze, A.C. (2006). Soil properties and management strategies for some sub-humid savanna zone Alfisols in Kaduna State, Nigeria. *Samaru Journal of Agricultural Research*, 22: 3-14.

Ogunwole, J.O., Babalola, O.A., Oyinlola, E.Y. and Raji, B.A. (2001). A pedological characterization of soils in the Samara area of Nigeria. *Samaru J. Agric. Res*., 17:71-77.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. (2002). *Laboratory Methods of Soil Analysis: A Working Manual*. 2nd edition. TSBF-CIAT and Sacred Africa, Nairobi, Kenya.

Palm, C.A., Gachengo, C.N., Delve, R.J., Cadish, G. and Giller, K.E. (2001). Organic inputs for soil fertility management in tropical agroecosystems: Applications of an organic resource database. *Agric. Ecosystems and Environment*, 83: 27-42.

Palm, S.A., Myers, R.J.K. and Nandwa, S.M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. *In: Replenishing Soil Fertility in Africa. SSSA Special publ. no. 51*: 193 – 217. SSSA, ASA. Madison.

Probert, M.E., Delve, R.J., Kimani, S.K and Dimes, J.P. (2005). Modelling nitrogen mineralization from manures: representing quality aspects by varying C: N ratio of sub-pools. *Soil Biology and Biochemistry*, 37(2): 279 - 287.

Sanginga, N. (2003). Role of biological nitrogen fixation in Legumes Based Cropping Sysyems: A case study of West Africa farming systems. *Plant and Soil*, 252: 25 – 30.

Sanginga N., Okogun J. A. R., Diels J., Vanlauwe B., Carsky R. J. and Dashiell K. (2001). Nitrogen contribution of promiscuous soybean in maize cropping systems. In Tian, G., Ishida, F., Keatinge, J.D.H.(Eds.), *Sustaining Soil Fertility in West Africa*. SSSA Spec. Publ. no. 58, SSSA, Madison, WI, USA, p. 69-89.

Shobayo, A.B., Malgwi, W.B., Hussaini, G.M., Gabassawa, A.I. and Yamusa, A.M (2018). Properties and Classification of wetland soils of Bomo Flood plain in the Northern Guinea Savanna, Nigeria. *Samaru Journal of Agricultural Research,* 25: 94 – 106.

SPSS) (2015). Statistical Package for Social Scientists 23.0 command syntax reference 2015, SPSS INC. Chicago USA.

Vanlauwe, B., Aihou, K., Houngnandan, P., Diels, J., Sanginga, N. and Merckx, R. (2001). Nitrogen management in “adequate” input maize-based agriculture in the derived savanna benchmark zone of Benin Republic. *Plant and Soil* 228: 61-71.

Weil, R. R., and Magdoff, F. F. (2004). Significance of soil organic matter to soil quality and health. In F. Magdoff and R.R. Weil (Eds): *Soil Organic Matter in Sustainable Agriculture*, 45–65. (Boca Raton, FL: CRC Press).

Yengwe, J., Amalia, O., Lungu, O.I and De Neve, S. (2018). Quantifying nutrient deposition and yield levels of maize (Zea mays) under *Faidherbia albida* agroforestry system in Zambia. *European Journal of Agronomy*, 99: 48 – 155.

Yusuf, A.A. and Yusuf, H.A. (2008). Evaluation of Strategies for Soil Fertility Improvement in Northern Nigeria and the Way Forward. *Journal of Agronomy, 7: 15-24.*

Yusuf, A. A., Iwuafor, E. N. O., Abaidoo, R. C., Olufajo, O.O and Sanginga, N. (2009). Grain legume rotation benefits to maize in the Northern Guinea savanna of Nigeria: Fixed-nitrogen versus other rotation effects. *Nutrient Cycling Agroecosystem*, 84: 129 – 139