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EFFECTS OF MINERALIZATION OF APPLE RING (*Faidherbia albida*) FOLIAGE AND UREA FERTILIZER ON SOIL MICROBIAL BIOMASS ON AN ALFISOL IN NORTHERN GUINEA SAVANNA OF NIGERIA

N. M. Chinke[1], S. Hamzat[1], E.Y. Oyinlola[1], S.A. Yusif[2] and F.J. Abubakar[1]

[1]Department of Soil Science, Ahmadu Bello University, Zaria
[2]Department of Soil Science, Federal University Dutse

ABSTRACT

The role of mineralized Apple-ring (*Faidherbia albida*) foliage and urea fertilizer on soil microbial biomass in a Northern Guinea Savanna Alfisol, Nigeria was assessed in the screen house using maize (Sammaz 32 variety) as the test crop. The treatments consisted of five Apple-ring (AR) tree foliage levels (0, 2, 4, 6 and 8 tonsha^{-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} equivalent to 0, 0.13, 0.23 and 0.46 g pot^{-1} respectively) laid out in a completely randomized design with three replications. Results of the plant analysis showed that apple ring foliage contained 428.3 g kg^{-1} organic carbon (OC), 29.8 g kg^{-1} nitrogen (N), 1.94 g kg^{-1} phosphorus (P), 37.5 g kg^{-1} potassium (K), 17.1 g kg^{-1} calcium (Ca). The C: N ratio of the foliage was found to be low indicating apple ring ability for improving and sustaining soil health and crop productivity even under long term crop production. The highest yield of microbial biomass carbon (MBC) (80.43 mg C kg^{-1}) and microbial biomass nitrogen (MBN) (47.13 mg N kg^{-1}) were observed with application of 8 tons ha^{-1} apple ring + 120 kg Nha^{-1} , having a C: N of 1.96 which is statistically the same with the C: N ratios of 2 tons ha^{-1} apple ring + 120 kgNha^{-1} (2.03) and 6 tons ha^{-1} apple ring + 120 kg Nha^{-1} (2.05), indicating that decomposition will be fastest due to higher carbon and nitrogen contents and 8 tons ha^{-1} apple-ring + 120 kg Nha^{-1} (urea) would be the best treatment combination for sustainable maize production under continuous intensive cultivation.

Keywords: Apple-ring foliage; mineralization; soil microbial biomass; maize.

INTRODUCTION

The ability to have good and adequate crop management for enhanced soil and crop productivity is a big constraint to sustainable agricultural production. Sub-optimal soil fertility status as a result of constant annual crop harvests (that deplete soil of nutrients), leaching of soil nutrients (leading to low nutrient use efficiency), and loss of biodiversity (which retards biological activities, thus stagnating nutrient recycling) are among the leading factors hampering sustainable agricultural intensification in Nigeria (Hamzat, 2022). Soil fertility management and improvement approaches using inorganic fertilizers are not only expensive but tend to hasten the degradation of the soil ecosystem with all its attendant effects (such as soil acidity, nutrient imbalance leading to poor soil quality and health) if inappropriately used. Ameliorating such conditions by the application of organic amendments has yielded good results (Tsefaye and Lemma, 2019; Yengwe *et al*., 2018a; Eche *et al*., 2014; Mohammed, 2013). Sufficient contact between the organic and inorganic fertilizers is required to achieve these positive interactions.

Nitrogen is the most important mineral nutrient limiting maize production in Nigeria savanna (Eche *et al*., 2014; Yusuf *et al*. 2003). Soil nitrogen deficiency has been addressed by the application of inorganic N fertilizers and this has brought increase in yields of cereal crops. Maize is known to tolerate high rate of nitrogen fertilizer without any depression in yields (Vanaraj and Paragasa, 2021). However, too much N fertilization of maize have been shown to result in land degradation, environmental pollution and soil health hazards (Adak *et al*., 2014; Eche *et al*., 2014) leading to economic loss to farmers. Burgeoning population growth, increased industrialization and urbanization has resulted in continuous intensive maize cropping on agricultural lands in Sub-Saharan Africa, especially in the Northern Guinea savanna of Nigeria in order to meet the target for food security and sustainable food production (FAO, 1995). Therefore, if crop productivity must be intensified, ways of making maximum use of land must be exploited to reduce land degradation and soil health problems, which occur due to continuous intensive cultivation and inappropriate fertilizer N application. Appropriate measures to restore soil fertility and maintain sustainable crop productivity have to be put in place.

Apple-ring (*Faidherbia albida*) or fertilizer tree as also called is native to semi-arid regions of Africa and has been observed to increases maize (*Zea mays*) yields when grown in its immediate surrounding (Akpalu, *et al*., 2020; Yengwe *et al*., 2018a). About 54% of farmers reported that where Apple-ring exists on the farm, crops perform better than in areas without the trees (Akpalu *et al*., 2020; Yengwe *et al*., 2018a; Sanda and Atiku, 2013). Research done by the Forestry Research Center (FRC) in Central Ethiopia, reported increase of 43% in wheat yields grown near an Apple-ring tree (Laike, 1992). Apple-ring has been reported to significantly improve soil fertility and reduced the cost of purchasing mineral fertilizers (Akpalu *et al*., 2020; Tesfaye and Lemma, 2019; Yengwe *et al*., 2018a; Umar *et al*., 2013; Sail, 1992). The yearly litter fall under matured trees of Apple-ring was shown to add high amounts of nitrogen to the surface soil at the on-set of the growing season. Light and rainfall interception were also minimized due to the tree's open canopy (Yengwe *et al*., 2018b). These conditions are favourable for maize production and studies showed that maize production was doubled when intercropped with Apple-ring (Wahl and Bland, 2013). Gelaw *et al.* (2014) investigated the effects of the presence of Apple-ring on the yield of maize (*Zea mays L.*) and sorghum (*Sorghum bicolor L. Moench*) have been reported to be increased significantly by 56% on average under the tree canopies compared to outside of the canopies. Work done have shown that leaves of Apple-ring have the potential to increase crop productivity between 30–200% in different crops (Rhoades, 1995). This was attributed to increases in soil organic matter, total nitrogen, and two to five times as much biological activity. Leaf fall has been observed by many researchers to be the key source of nutrients and enhanced soil organic matter due to increased mineralization rate as a result of increased microbial activity (especially during the rainy season) from which the soils health is improved (Akpalu *et al*., 2020; Tesfaye and Lemma, 2019; Yengwe *et al*., 2018b; Umar *et al*., 2013).

However, little or no work has been done on mineralization effect of Apple-ring foliage on soil microbial activity knowing the potential benefits of this fertilizer tree in the improvement of soil health. The aim of this study, therefore, was to assess the effect of mineralized Apple ring foliage and urea fertilizer on soil microbial biomass in the Nigeria Northern Guinea savanna Alfisols.

MATERIALS AND METHODS

Experimental Site

Soil of the experimental site is classified as Typic Haplustalf in the USDA Soil Taxonomy system (Ogunwole *et al.,* 2001). The potential of Apple ring to improve soil properties was evaluated for 3 months in the Screen house of Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria (11º 9′ N, 7º 36′E). The experimental soil was collected from plot S1 of Institute for Agricultural Research (IAR) farm, Samaru, Zaria in the Northern Guinea savanna with the coordinates: Latitude 11º25′20″ N, and Longitude 7º 08′30″E (Yusuf and Yusuf, 2008).

Soil Sampling and Analysis

The soil samples were taken from the topsoil (0-15 cm) of the field. The samples were air-dried crushed and sieved through 2 mm mesh sieve and subsampled for soil physical and chemical properties using Anderson and Ingram (1993) method. Then 4 kg soil samples were weighed into each of the 5-liter capacity plastic pots for the study.

Soil samples collected before and after the decomposition studies were analyzed for various parameters such as Particle size distribution estimation by the hydrometer method described by Gee and Dr. (2002); soil pH in 1: 2.5 soil water ratio in 0.01 M $CaCl_2$ suspension with the glass electrode pH meter. Organic carbon by the Walkley and Black wet oxidation method (Okalebo *et al.,* 2002); total N in the soil samples by Kjeldahl procedure (Bremner and Mulvaney, 1982); available P by the Bray 1 method as described by (Okalebo *et al.,* 2002) 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). Micronutrients (Zn, Cu, Fe, Mn) were determined using 1 % EDTA and the elements estimated by AAS (Okalebo *et al.,* 2002).

Soil Microbial Biomass Analysis

Microbial biomass C (SMBC) and N (SMBN) were estimated using the chloroform fumigation – extraction technique (Brookes *et al.,* 1985; Vance *et al.,* 1987; Okalebo *et al.,* 2002) which allows for microbial biomass C and N to be determined in the same extract and does not require for the soil microbial community to be in equilibrium (as required for substrate induced respiration) (Schinner *et al.,* 1995). After extraction with K_2SO_4 (extraction ratio 1:4), total extractable C and N were determined by the dichromate oxidation (Nelson and Sommers, 1982) and Kjeldahl (Bremner and Mulvaney, 1982) methods for C and N respectively. For conversion of total C and N to biomass C and N, factors 2.67 (Vance *et al.,*

1987) and 1.46 (Brookes *et al.*, 1985) were used respectively. Ratios of total C to total N (C: N ratio) and microbial C to microbial N (biomass C: N ratio) were also determined from the data.

Characterization of the Apple ring Foliage and Plant 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).

Treatment and Experimental Design

The treatments consisted of 5 rates of apple-ring (*Faidherbia albida*- FA) (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 in completely randomized design (CRD) with three replications, giving a total number of 60 pots.

Incubation Studies

Four kilograms (4kg) of sieved soil was weighed out and 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) to drain. The difference between the non - saturated and saturated soil was the amount of water applied. Soils from each pot were sampled at 0, 3, 6 and 9 weeks for the determination of available nitrogen (NO_3^--N and NH_4^+-N).

Net Mineralization Index

The net mineralization index was then calculated using the formula below:

N mineralization (%) = 100 x (Mineral-N_{input} – Mineral-$N_{control}$)/N added

Where:

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

The net immobilization was not determined as the study focused on mineralization rate of apple-ring tree foliage only.

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 Experimental Site

Results of some selected 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}) (Chude *et al.*2012; Jones (Jr), 2001;1998). 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.

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})		
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

Note: *ECEC = TEB + EA; Source = Chude *et al.*, 2012; Jones (Jr), 2001.

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. 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.

Characteristics of Apple-ring Tree Foliage Used in the Study

Though, all nutrients in soil organic matter may not be available to a crop, but data obtained can give an estimate of the amount of organic material (Palm *et al.*, 1997) in it. Result revealed the properties of the Apple-ring foliage used in the study (OC, 428.3 g kg^{-1}; N 29.8 g kg^{-1}; K, 37.5 g kg^{-1}) (Table 2) were high while P (l.94 g kg^{-1}) was low. The C: N ratio was 14.1, suggesting rapid decomposition rate resulting in a net release of nutrients when applied to the soil. This agrees with the findings of Eche (2011) and Adeboye *et al*. (2006) who observed higher nutrient release due to rapid decomposition rate as a result of C: N ratio below 30:1. 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 of 210, 198, 114 and 12.1 g kg^{-1} respectively were within safe limits and showed lignin + polyphenol: N ratio of less than 10 which is an index for predictor of N mineralization (Fox *et al.*, 1990).

Table 2: Characteristics of Apple-ring foliage used in the study

Parameter	Concentration (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.

Table 3: Effect of mineralization of Apple ring 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	
Apple Ring tha^{-1} (AR)								
0 AR	2.63b	3.10	2.94ab	8.67	9.58	8.32b	7.41	25.31
2 AR	3.68a	3.10	3.41ab	10.19	9.77	8.14b	10.31	28.22
4 AR	3.78a	3.10	3.47a	10.35	12.48	11.75a	9.04	33.27
6 AR	3.31ab	2.73	2.78ab	8.82	10.31	8.50b	7.96	26.77
8 AR	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 AR	NS	NS	NS		NS	NS	NS	

NS= not significant at 5% level of significance; AR = 0, 2, 4, 6 and 8 $tonsha^{-1}$ of apple-ring; urea = 0, 30,60 and 120 $kgNha^{-1}$ = 0, ¼, ½ and FRR (full recommended rate), Net min= Net mineralization.

The highest release of ammonium (NH_4^+-N) and nitrate-N (NO_3^- -N) was recorded from $4tonsha^{-1}$ apple-ring at 3 and 9-weeks with NH_4^+-N having 3.78 mg kg^{-1} and 3.47 mg kg^{-1} at 3 and 9 weeks respectively while NO_3^- -N recorded 12.48 mg kg^{-1} and 11.75 mg kg^{-1} at 3 and 6 weeks respectively (Table 3), followed by $2tonsha^{-1}$ apple-ring. This showed that at $4tonsha^{-1}$ application of apple ring, the optimum nutrient required by microorganisms has been attained in immobilization, and mineralization began. This also reflected in the cumulative N mineralized (43.62 mg kg^{-1}), compared to other treatments (Table 3). The lowest values of ammonium-N (NH_4^+-N) and nitrate-N (NO_3^- -N) were recorded with the application of $8tonsha^{-1}$ apple-ring. This could be due to the higher organic carbon content resulting in more microbial biomass with high N demand. The low C: N ratio obtained in Table 2 indicates net N mineralization and thus will enhance soil fertility and crop productivity. This also indicates that apple-ring foliage maybe an excellent N fertilizer for maize crop since it provides plant available N as NH_4^+ and from organic N mineralization to meet the crop N demand.

Result obtained showed more release of NO_3^- -N compared to NH_4^+-N indicating the presence of heterotrophic microbes (*Nitrobacter* sp) which takes up more NO_3^- -N than NH_4^+-N (Martin and Louise, 2003). There was no significant different in the interaction between apple-ring and urea.

Effect of Apple-ring and Urea on Soil Microbial Biomass after Cropping

Soil microbial biomass Carbon (MBC)

Result obtained showed a general decrease in MBC with increase in urea (Table 4). The control had the lowest value (23.17 mg kg^{-1}) while the highest value obtained was recorded with 30kgNha^{-1} (46.92 mg kg^{-1}) though not statistically different from 60kgNha^{-1} (46.53 mg kg^{-1}) and 120kgNha^{-1} (42.87 mg kg^{-1}). The slight decrease in MBC with increase in urea application showed the effect of crop uptake and immobilization of carbon by microbes for their body building. In the apple-ring tree foliage treatment, MBC increased with increase in Apple-ring with 8tonsha^{-1} apple-ring having the highest MBC (76.44 mg kg^{-1}), showing the benefit of rapid mineralization of apple-ring foliage due to its low C: N ratio (Table 2) and also in helping to reduce greenhouse gas emission and improve soil health.

Soil microbial biomass N (MBN)

There was significant ($p<0.05$) difference in the results with apple-ring and urea on microbial biomass N (MBN). In the urea treated pots, 120kgNha^{-1} gave the highest MBN (24.18 mg kg^{-1}) while the lowest value (10.85 mg kg^{-1}) was obtained from the control. The increase in MBN with increased application of urea suggests that the higher the MBN load in soil, the more N is being released, though application of high amount of urea have been reported to cause detrimental environmental impacts such as soil degradation, low fertility status and crop yield due to increase in soil acidity (Adak *et al*., 2014; Eche *et al*., 2015; Abaidoo *et al*., 2013). In the apple-ring treatment, MBN increased at 2tonsha^{-1} followed by a decrease up to 6tonsha^{-1}apple-ring and then increased at 8tonsha^{-1}apple-ring, suggesting that soil microflora can compete with plants for ammonium and convert it into microbial proteins, thus immobilizing the nitrogen into an organic or temporarily unavailable form. Generally, the higher MBN observed in the apple-ring treated soil did not result in higher net mineralization than urea treated soils, suggesting that MBN may not be a good indicator of plant available N. There was significant ($p<0.05$) interaction between apple- ring and urea on MBN alone (Table 5). At 2tonsha^{-1} apple-ring MBN decreased with increase in urea application with 30kgNha^{-1} recording 27.07 mg kg^{-1}while 120kgNha^{-1} (21.80 mg kg^{-1}), indicating that synchronization of apple-ring with urea at these rates were sufficient for the nutrients required by the heterogeneous microbes present in soil. Combined application of 8tonsha^{-1} apple-ring + 120kgNha^{-1} gave the highest (47.13 mg kg^{-1}). The lowest value was recorded at 6tonsha^{-1} apple-ring + 30kgNha^{-1} (10.47 mg kg^{-1}) though statistically the same with 4tonsha^{-1} apple-ring + 30kgNha^{-1}, 4tonsha^{-1} apple-ring + 60kgNha^{-1}, 4tonsha^{-1} apple-ring + 120kgNha^{-1}, 6tonsha^{-1} apple-ring + 30kgNha^{-1}, 6tonsha^{-1} apple-ring + 60kgNha^{-1} and 8tonsha^{-1} apple-ring + 30kgNha^{-1} having 15.70, 18.83, 19.77, 10.47, 15.07 and 19.27 mg kg^{-1} respectively. Increase in MBN with increased level of apple-ring tree foliage from 4 to

6tonsha^{-1} apple-ring at same urea rate of 60kgNha^{-1} could be due to competition for nutrient as a result of insufficient nutrients mineralized leading to nutrient immobilization by microbes. Steele and Vallis (1988), stated that under certain conditions, soil microbes can compete with plants for ammonium and convert it into microbial proteins, thus immobilizing the nitrogen into an organic or temporarily unavailable form. In general, the synchronization of higher level of apple-ring with urea favours mineralization as observed with 8tonsha^{-1} apple-ring treatments combined with urea (Table 5). Therefore, increasing the amount of apple-ring up to 8tons ha^{-1} and in combination with higher levels of mineral N, such as 60kgNha^{-1} and 120kgNha^{-1}, will result in increased levels of cellulose, hemicellulose and lignin contents, thereby increasing the populations of different microorganisms resulting in increased rate of mineralization. However, low rate of N would lead to immobilization of nutrient.

MBC: MBN (C: N) ratio

Result of the biomass ratios are presented in Table 4. There was a significant difference ($p<0.05$) in MBC: MBN ratio due to application of urea. Biomass C: N ratio decreased generally, suggesting rapid uptake by plant as N in urea is in the plant available form. The lowest value was observed with 120kgNha^{-1} (1.87) though statistically the same with control (2.24) and 60kgNha^{-1} (2.43). The highest value recorded was 3.26 from 30kgNha^{-1}. This agrees with the findings of Mohammed (2013), who reported that soils having C: N ratios less than 10 will rapidly decompose and release more nutrients into soils.

Table 4: Effects of urea and apple-ring on soil microbial biomass carbon and nitrogen in the screen house after cropping

Treatment	MBC (mg kg^{-1})	MBN (mg kg^{-1})	MBC: MBN
Urea			
Control	23.17b	10.85c	2.24b
¼ RR	46.92a	17.67b	3.26a
½ RR	46.53a	20.49ab	2.43b
FRR	42.87a	24.18a	1.87b
S.E ±	2.237	1.999	0.362
Apple Ring			
Control	17.53c	12.24c	1.76c
2 AR	48.75b	21.62b	2.66bc
4 AR	49.81b	17.33bc	3.24b
6 AR	49.67b	13.39c	5.06a
8 AR	76.44a	27.35a	3.81b
S.E	2.501	2.235	0.405
Interaction			
AR X Urea	NS	*	NS

N. B. * = significant at 0.05 level of probability; NS= Not significant at 0.05 level of probability, statistically significant using DMRT; RR= recommended rate, FRR=Full fertilizer recommendation rate; AR = Apple ring

In the apple-ring treated soils 6tonsha^{-1}apple-ring had the highest ratio (5.06) though less than 10: 1. This was attributed to the higher content of organic matter leading to higher microbial C in soil. This agrees with the findings of Weil and Magdoff, (2004) who also reported that the higher the level of organic matter, the more the yield of microbial biomass C in soil. They attributed it to the fact that increases in soil organic matter (SOM) are usually associated with similar increases in microbial biomass, because organic matter provides the substrates for the microorganisms. Though the MBC: MBN ratios of 4 and 8tonsha^{-1} apple-ring are statistically the same, there will be longer lasting mineralization rate at 8tonsha^{-1} apple-ring as a result of its higher MBC and MBN compared to other treatments, suggesting its benefit for sustainable maize production under long term continuous intensive cropping.

Table 5: Interaction of apple ring and urea fertilizer on MBC, MBN and MBC: MBN ratio

Treatment	MBC	MBN	MBC: N
AR x Urea			
2AR + ¼ RR	55.37	27.07b	2.24
2AR + ½ RR	44.48	20.67b	2.22
2AR + FRR	40.73	21.80b	2.03
4AR + ¼ RR	53.92	15.70c	3.81
4AR + ½ RR	46.15	18.83c	2.48
4AR + FRR	37.81	19.77c	2.18
6AR + ¼ RR	41.60	10.47c	5.64
6AR + ½ RR	51.92	15.07c	3.78
6AR + FRR	42.27	20.40b	2.05
8AR + ¼ RR	65.60	19.27c	3.42
8AR + ½ RR	73.01	30.93b	2.66
8AR + FRR	80.43	47.13a	1.96
S.E ±	5.511	5.490	0.920
LOS	NS	*	NS

N. B. * = significant at 0.05 level of probability; NS= Not significant at 0.05 level of probability, statistically significant using DMRT; RR= recommended rate, FRR=Full fertilizer recommendation rate; AR = Apple ring

CONCLUSION

The objective of this study was to assess the nitrogen nutrient potential of apple-ring (*Faidherbia albida*) foliage in improving soil microbial biomass in an Alfisol, Samaru, NGS, Nigeria. Results obtained showed high organic carbon content from the foliage as well as substantial amounts of nitrogen enhanced soil microbial biomass. The C: N ratio of the foliage was found to be low indicating it high potential for improving and sustaining soil health and crop productivity even under long term crop productivity. Application of 8tonsha^{-1} apple-ring in combination with 120kgNha^{-1} gave the highest MBC (80.43 mg C kg^{-1}) and MBN (47.13 mg N kg^{-1}). The lowest MBC: MBN ratio of 1.96 was obtained with combined application of 8tonsha^{-1} apple-ring + 120kgNha^{-1} urea though statistically same with 2tonsha^{-1} apple-ring + 120kgNha^{-1} (2.03) and 6tonsha^{-1} apple-ring + 120kgNha^{-1} (2.05), indicating that decomposition will be fastest due to higher carbon and nitrogen contents and 8tonsha^{-1} apple-ring + 120kgNha^{-1} (urea) would be the best treatment combination for sustainable maize production under continuous intensive cultivation.

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