



Nitrogen Mineralization Rate in Soil Amended with Organic and Inorganic Fertilizer for Production of *Morinda citrifolia* L.



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Abstract

Nitrogen (N) plays a key role in agriculture systems by increasing crop yield. An understanding of the rate of N mineralization in the soil for *Morinda citrifolia* production will help to achieve a cost effective N fertilizer application. Hence, an incubation study was conducted to investigate the effects of organic amendments on soil N release. The experiment was a 2 x 8 factorial experiment: top soil and river sand amended with 160 kg N ha⁻¹ biochar, biochar + Poultry manure (PM), PM, N:P:K 15:15:15, biochar + N:P:K, PM + N:P:K, biochar + PM + N:P:K and control. Data collected were subjected to Analysis of Variance (ANOVA) using Genstat statistical software package. Significant means were separated using Duncan's Multiple Range Test at $p < 0.05$. Results indicated that top soil had a significantly higher level of NH_4^+ N mineral release than river sand throughout the 98 days of incubation period. Soil with N: P: K 15:15:15 (10.02 mg/kg) at 14 days after incubation (DAI) had the highest. However, at 98 DAI, soil amended with PM (1.45 mg/kg of NH_4^+ N) was significantly higher ($p < 0.05$) compared to all other amendments. Top soil for raising seedlings increased the release of NH_4^+ - N, while River sand increased the release of NO_3^- -N. It was recommended that poultry manure could be used for soil amendment and Noni in top soil will sustain the release of NH_4^+ -N and NO_2^- - N mineral to the plant over a longer period of time.

Keywords: Soil, Nitrogen, Amendment, Fertilizer, *Morinda citrifolia* and Mineralization

INTRODUCTION

Organic inputs used in soil fertility management commonly consist of livestock manures, crop residues, woodland litter, biochar, household organic refuse, composted plant biomass harvested from within or outside the farm environment for purposes of improving soil productivity (Blair and Crocker, 2000). Organic resources have multiple functions in soil, ranging from their influence on nutrient availability to modification of the soil environment in which plants grow. Apart from providing essential plant nutrients, they contribute directly towards the building up of soil organic matter (SOM) and its associated benefits (Blair and Crocker, 2000). Nitrogen is the first nutrient of concern to farmers and scientist, with regards to soil testing and fertilizer application (Massignam *et al.*, 2009). Nitrogen plays a key role in agriculture by increasing crop yield (Massignam *et*

al., 2009). Nitrogen not only enhances the yield but also improves the food quality (Ullah *et al.*, 2010). Optimum, rate of N increases photosynthetic processes, leaf area production, as well as net assimilation rate (Ahmad *et al.*, 2009). Available N is the inorganic form that can be readily absorbed by plant. The main forms absorbed directly are NO_3^- and NH_4^+ (Adepetu *et al.*, 2014). *Morinda citrifolia* - A tree in the family Rubiaceae commonly known as Noni or Indian mulberry and a variety of other names in various regions, is a small evergreen tree or shrubs that originated from Indonesia and spread to the Pacific Basin, Philippines, Japan, China, and Australia. Its fruit and leaves are a major staple or famine food in some locations and medicine or dyes in other places. It contains several medicinal active compounds, e.g. anthraquinones, terpenoids, alkaloids, sitosterol, carotene, flavones and glycosides that exhibit various therapeutic

effects such as anti-bacterial, anti-viral and anti-cancer activities (Wang *et al.*, 2002). The noni tree reaches a height of 3-10 m at maturity and it start flowering within 9 months on the field when planted. An understanding of the rate of nitrogen mineralization from fertilizer in the soil for noni production will help to achieve a successful, cost effective and environmental friendly farming of the crops. Hence the need to determine the effect of organic and inorganic fertilizer on the nitrogen release pattern of the soil used for noni production.

MATERIALS AND METHODS

Nitrogen mineralization from organic and inorganic fertilizer in two media was determined in an incubation study in the laboratory in which top soil and river sand collected from arboretum for raising seedlings in the Forestry Research Institute of Nigeria (FRIN), Ibadan were used. 100g air-dried sample of each media which had been passed through 2 mm sieve were dispensed into each incubation vessel (100ml). Poultry Manure, biochar, NPK and their mixtures were applied at rate of 160 kg N ha⁻¹ (Table 1) for each treatment separately into each plastic, mixed and kept at field capacity with deionized water. Each treatment was replicated four times and these were kept inside a laboratory incubator at 27°C for 98 days. The experiment was a 2 x 8 factorial combination with 4 replicates laid out in a Completely Randomized Design (CRD). Factor-1: Media (Top soil and River sand) and Factor-2: Amendments: T1: Control, T2: Poultry manure (PM), T3: N:P:K 15:15:15, T4: PM + N:P:K 15:15:15, T5: *Gliricidia sepium* (Gs) Biochar, T6: Gs Biochar + (PM), T7: Gs Biochar + N:P:K 15:15:15, T8: Gs Biochar + PM + N:P:K 15:15:15.

Laboratory Study

The top soil used for the study was analysed to determine the soil chemical properties. The soil pH was determined in 1:2 soil: water suspension. Ten grams of 2 mm sieved soil sample was weighed into the sample bottle and 20 ml of distilled water was added to it. The samples were stirred with glass rod for some minutes and were left to equilibrate for 30 minutes. At the end of 30 minutes the pH of the soil was taken using a standard calibrated electrode pH meter (Thomas, 1996). Total soil organic carbon was determined using acid dichromate wet-oxidation procedure of

Walkey and Black method, as described by Nelson and Sommers (1996). Soil organic matter was derived by multiplying the value of SOC by a Bemmelen's factor of 1.724 (Nelson and Sommers, 1996). Total nitrogen was determined using micro-Kjeldahl method (Nelson and Sommers, 1996). Available P was determined using Bray-1 method. The available P was extracted using Bray-1 extractant and the concentration of the available P in the extract was determined by the molybdate blue method using spectrophotometer at 882 nm wavelength (Kuo, 1996). Soil samples were also extracted with 1 N NH₄OAc and Na and K were determined using flame photometer while Mg and Ca were determined from the extract with atomic absorption spectrophotometer (AAS 210-VGP) (Thomas, 1982). Soil micronutrients were analysed using atomic absorption spectrophotometer (AAS). The chemical properties of the soil amendments (biochar and poultry manure) were also determined. 0.5 g of soil amendments were weighed and digested using Sulphuric acid and selenium catalyst and N was determined by Kjeldahl method. Also, phosphorus contents of the digested organic amendments were determined by the vanado-molybdate method using spectrophotometer at 410 nm wavelength, while Na and K were determined using flame photometer. Whereas, Mg and Ca were determined from the digest with atomic absorption spectrophotometer (AAS 210-VGP) (Thomas, 1982).

Incubation study

Samples were taken at 1, 3, 7, 14, 28, 49 and 98 days after incubation and were extracted with 2M KCl for determination of ammonium – nitrogen, nitrate and nitrite - nitrogen release (Dai *et al.*, 2008; Medina *et al.*, 2009; Wang *et al.*, 2010) using the procedure of Macgill Environmental Research laboratory (MERL) 2000; where 5 ml of the filtrate from KCl was taken into a 50 ml beaker and 2.5 ml of alkaline phenol, 1 ml sodium potassium tartrate and 2.5 ml sodium hypochlorate were added and the mixture was shaken well and read colorimetrically at 636 nm to quantify ammonium nitrogen in part

Table 1: Soil nutrient sources and application rate for Noni family member (Coffee) seedlings

Nutrient	Fertilizer type	% Carrier	Quantity	Quantity
N	(Urea)	46% N	160	142.73
P	(KH ₂ PO ₄)	22.7% P	50	44.6
K	(KCl)	60% K	70	62.44
B	(Sodium)	99% B	0.5	0.45
Zn	(ZnO)	99%	1	0.89
Ca	(CaO)	99%	80	71.36
Mg	(MgO)	99%	40	35.68

Kinloch: VOLHOUBARE LANDBOU, RSA. 1999

per million (ppm). Similarly, 10 ml of the filtrate from KCl was taken into a 50 ml flask and 2 ml of Brucine reagent and 10 ml of concentrated Sulphuric acid were added and mixed together. Then, the mixture was allowed to stand for 10 minute before making to mark with distilled water. The solution was read colorimetrically at 470 nm to quantify nitrate nitrogen (NO₃-N) in ppm. Also, another 10 ml from the filtrate from KCl was taken into another 50 ml flask and 2 ml of 2N HCl, 2 ml sulphanilic acid and 10 ml alpha-naphthylamine were added and read colorimetrically at 520 nm after 20 minutes to quantify nitrite nitrogen (NO₂-N) in ppm.

Statistical analysis:

Data collected were subjected to Analysis of Variance (ANOVA) using Genstat Statistical Software package. Means were separated using Duncan multiple range test (DMRT) at 5% level of significance.

RESULTS

The result revealed that the top soil had pH value of 6.47 and total N value of 0.14%. The available P value was 4.26 mg/kg, exchangeable bases (Cmol⁺ kg⁻¹); K⁺, Na⁺, Ca²⁺ and Mg²⁺ had the values 0.06, 0.09, 3.0 and 0.3 respectively. The micro-nutrients (mg kg⁻¹); Mn²⁺, Fe²⁺, Cu²⁺ and Zn²⁺ had the values 57.7, 20.8, 10.5 and 16.9, respectively (Table 2). The sand, silt and clay (g kg⁻¹) were 825, 105 and 70 respectively. The amounts of total N, P, K, Na, Ca, Mg and Organic Carbon in Poultry manure added to the soil at the rate of 160 kg N ha⁻¹ were 13, 8.1, 2.0, 1.6, 15, 15, and 151 g/kg respectively. However, *Gliricidia sepium* (GS) Biochar also applied at the rate of 160 kg N ha⁻¹ had total N, P, K, Na, Ca, Mg and

OC of 10.3, 2.8, 4.0, 1.4, 1.7, 1.4 and 982.8 g/kg respectively (Table 3). There was no significant difference in the interaction of amendments applied with the media at Day 1 of incubation but the rate at which NH₄⁺-N was released in top soil (3.66 mg/kg) during this period was significantly higher than that released from river sand (2.11 mg/kg). Also, there was a significant difference in the release pattern of NH₄⁺-N from amendments applied; where biochar, biochar + Poultry Manure (PM) and Control (No amendment) with 2.17, 2.52 and 2.43 mg/kg respectively were significantly lower than those of PM, N: P: K (15:15:15), biochar + N: P: K, PM + N: P: K and biochar + PM + N: P: K with 3.08, 3.23, 3.07, 3.24 and 3.37 mg/kg, respectively (Table 4). By the third day after incubation (DAI), there was a significant difference in the interaction of amendment with the soil types. NH₄⁺-N released from top soil (5.56 mg/kg) during this period was significantly higher than that released from river sand (2.93 mg/kg) which also revealed a higher NH₄⁺-N release during this period compared to that of 1 DAI (Table 4). Furthermore, amendment with N: P: K alone in interaction with Top soil at 3 DAI with 7.27 mg/kg NH₄⁺-N released was significantly higher when compared with other amendments in interaction with both soil type during this period. While amendment with biochar alone and biochar + PM in interaction with river sand had 1.70 and 1.10 mg/kg NH₄⁺-N released respectively. These were the least when compared with other amendments in interaction with the medium, during the same period. Also at seven (7) DAI, there was a significant difference (P = 0.05%) in the interaction of amendment with soils till the end of the experiment. The combination of biochar + PM + N: P: K as soil amendment recorded a significantly higher NH₄⁺-N released (5.77 mg/kg) compared with other treatments. There was no significant difference between the amount of NH₄⁺-N released from N: P: K (4.26 mg/kg) and that of PM + N: P: K (4.29 mg/kg), while NH₄⁺-N released from biochar, biochar + N: P: K and control (2.47, 2.34 and 2.41 mg/kg) respectively were significantly lower, compared to those released from other amendments during the same period (Table 4). Furthermore in Table 5, biochar + PM + N: P: K and PM + N: P: K from Top soil had NH₄⁺-N values of 7.38 and 6.98 mg/kg respectively. These were not significantly different from each other but were significantly

higher than other amendment/medium interaction at 7 days after incubation.

Table 2: Physical and chemical properties of top soil used in the study

Property	Values
Sand (g/kg)	825
Clay (g/kg)	105
Silt (g/kg)	70
Textural class	Loamy sand
pH (H ₂ O)	6.47
OC (%)	1.7
TN (%)	0.14
Avail. P (mg/kg)	4.26
K (cmol/kg)	0.06
Ca (cmol/kg)	3.0
Mg (cmol/kg)	0.3
Na (cmol/kg)	0.09
Mn (mg/kg)	57.7
Fe (mg/kg)	20.8
Cu (mg/kg)	10.5
Zn (mg/kg)	16.9

Table 3: Chemical properties of the Biochar and Poultry Manure used in the Study

Chemical	Biochar	Poultry manure
Organic Carbon	982.8	151.6
Total Nitrogen	11.3	13.0
C/N ratio	86.7	11.6
Avail. P	2.8	8.1
Ca	1.7	15
Mg	1.4	15
Mn	9.4	0.28
Fe	9.4	1.02
Cu	9.8	0.04
Zn	14.7	0.4

Also, biochar interaction with River sand and River sand (control) recorded significantly lower values of NH₄⁺-N released (0.17 and 0.14 mg/kg), when compared with amendment/medium interaction at 7 DAI. At 14 DAI, the values of NH₄⁺-N released was the highest throughout the period of incubation, where NH₄⁺-N released from top soil (9.21 mg/kg) was significantly higher than that released from river sand (1.68 mg/kg) (Table 4). The N:P:K release of NH₄⁺-N (10.02 mg/kg) at

this period was significantly higher than that released from other amendments during the same period (Table 4). Furthermore, there was a significant difference in the release pattern of NH₄⁺-N from the soil types in interaction with amendments applied. Top soil amended with N:P:K recorded the significantly highest value of NH₄⁺-N (14.80 mg/kg); followed by Biochar + N:P:K with 12.37 mg/kg, then PM with 10.06 mg/kg followed by PM + N:P:K with 9.19 mg/kg. these were all significantly higher than the amount released by N:P:K from River sand (5.23 mg/kg) (Table 5). From 28 DAI to 98 DAI, Top soil with amendments maintained a significantly higher NH₄⁺-N release compared with River sand with amendments but the values of NH₄⁺-N released was generally reduced across this period (Table 4). Amendment of Biochar + PM + N:P:K released a significantly higher NH₄⁺-N (6.33 mg/kg) at 28 DAI but at 49 DAI and 98 DAI, PM amendment released significantly higher NH₄⁺-N (Table 4). Also, the interaction of amendments with soil types reveals that biochar + N: P: K interaction with top soil released a significantly higher value of NH₄⁺-N (9.69 mg/kg) compared to all other interactions at 28 DAI while at 49 and 98 DAI, PM recorded significantly higher NH₄⁺-N (7.75 and 2.71mg/kg) respectively compared to all other interaction across the same period. The amount of NO₃⁻ – N released in this study was lower when compared to that of NH₄⁺-N, indicating that NO₃⁻ – N was less available in the soil and amendments. There were significant differences in the interaction of amendments applied with the soil types from first day DAI to 98 DAI where River sand released significantly higher NO₃⁻ – N than Top soil, except at 14 DAI where the difference was not significant but river sand still maintained a higher value of 0.44 mg/kg compared to top soil value of 0.42 mg/kg of NO₃⁻ – N. Also, the N:P:K amendment released a significantly higher amount of NO₃⁻ – N compared to all other amendments in the study irrespective of the soil medium from 1 DAI to 98 DAI with the highest amount of release available at 3 DAI (1.39 mg/kg) followed by 7 DAI (1.23 mg/kg) while the least NO₃⁻ – N released was 0.43 mg/kg at 98 DAI (Table 4). Control soil recorded the least amount of NO₃⁻ – N from 3 DAI to 98 DAI and was also significantly lower than that released by soils with amendments (Table 6). River sand amended with N:P:K

revealed a significantly higher release of $\text{NO}_3^- - \text{N}$ than all others from 1 DAI to 98 DAI (Table 4).

The highest value of $\text{NO}_3^- - \text{N}$ released from N:P:K with river sand was 1.78 mg/kg at 3 DAI followed by 1.76 mg/kg at 7 DAI, while the least amount recorded from the same interaction was 0.65 mg/kg at 98 DAI. The interaction of top soil with PM + N:P:K ranked 2nd from 14 DAI to 98 DAI whose $\text{NO}_3^- - \text{N}$ release values were significantly higher than other interactions during the same period except for the values obtained from river sand interaction with N:P:K (Table 5). The $\text{NO}_2^- - \text{N}$ recorded the least available values when compared with $\text{NH}_4^+ - \text{N}$ and NO_3^- and the interactive effect of the soil types with amendments showed no significant difference in the release of $\text{NO}_2^- - \text{N}$ from 1 DAI to 98 DAI but the differences were significant from 3 DAI to 49 DAI. At 1 DAI, 7 DAI and 98 DAI, there was no significant difference in the rate at which $\text{NO}_2^- - \text{N}$ was released in River sand compared to Top soil while River sand recorded a higher value (0.016 mg/kg) than Top soil (0.011 mg/kg) at 1 DAI. But, at 3 DAI, 14 DAI, 28 DAI and 49 DAI, top soil recorded significantly higher amount of $\text{NO}_2^- - \text{N}$ released when compared to River sand. Furthermore, the interaction of PM + N:P:K with Top soil recorded a significantly higher value of $\text{NO}_2^- - \text{N}$ (0.06 mg/kg) released at 3 DAI compared to every other interaction during the same period. Likewise, the interaction of biochar + PM + N:P:K with Top soil also recorded a significantly higher value of $\text{NO}_2^- - \text{N}$ (0.14 mg/kg) at 7 DAI compared to other interaction. This was also the case at 49 DAI, where PM interaction with top soil recorded a significantly higher value of $\text{NO}_2^- - \text{N}$ (0.38mg/kg) compared with other interactions during the same period.

DISCUSSION

The Topsoil used for the research was loamy sand (USDA, 2010), which was deficient in total nitrogen (USDA-SCS 1974) and had low available P content (ENDMEMO 2015; Mallarino 2000). In this study, Top soil released a significantly higher $\text{NH}_4^+ - \text{N}$ concentrations from amendments compared to those of River sand throughout the duration of the experiment and this is because a higher population of ammonifying bacteria are expected in top soil with higher organic matter than that of river sand. The average amount of

$\text{NH}_4^+ - \text{N}$ released at 14 days after incubation (DAI) from Top soil was the highest compared to River sand throughout the duration of the experiment while top soil with N:P:K at 14 DAI was significantly higher than every other interaction in the study but at 98 DAI, soil amended with poultry manure released a significantly higher $\text{NH}_4^+ - \text{N}$ compared to other interactions (Tables 3 and 4).

Table 4: Effect of growth medium and amendment on NH_4^+ – N mineralization during 98-day incubation period

Factor	LEVEL	DAY 1	DAY3	DAY7	DAY14	DAY28	DAY49	DAY98
Medium	River sand	2.11 ^b	2.93 ^b	1.63 ^b	1.68 ^b	2.40 ^b	0.89 ^b	0.27 ^b
	Top soil	3.66 ^a	5.56 ^a	5.41 ^b	9.21 ^a	5.60 ^a	3.42 ^a	1.24 ^a
Amendment	CONTROL	2.43 ^b	3.32 ^{cd}	2.41 ^e	2.59 ^d	2.14 ^d	0.45 ^c	0.19 ^e
	PM	3.08 ^a	4.12 ^b	3.64 ^c	5.69 ^c	4.04 ^c	4.15 ^a	1.45 ^a
	N:P:K	3.23 ^a	6.49 ^a	4.26 ^b	10.02 ^a	3.96 ^c	1.52 ^{bc}	0.76 ^c
	PM + N:P:K	3.24 ^a	5.16 ^b	4.29 ^b	5.54 ^c	4.96 ^b	2.48 ^b	0.65 ^{cd}
	BIOCHAR	2.17 ^b	2.80 ^d	2.47 ^e	2.56 ^d	1.99 ^d	2.27 ^b	0.63 ^{cd}
	BIOCHAR + PM	2.52 ^b	3.54 ^{cd}	3.01 ^d	5.17 ^c	3.50 ^c	2.33 ^b	1.09 ^b
	BIOCHAR + N:P:K	3.07 ^a	3.28 ^{cd}	2.34 ^e	6.87 ^b	5.09 ^b	1.44 ^{bc}	0.43 ^d
	BIOCHAR + PM + N:P:K	3.37 ^a	5.23 ^b	5.77 ^a	5.14 ^c	6.33 ^a	2.59 ^b	0.80 ^c
Interaction								
M	X	A	Ns	0.58	0.21	0.42	0.37	0.92
								0.16

Means followed by the same letter in each column are not significantly different from each other ($P>0.05$)

Table 5: Influence of growth medium with amendment on NH_4^+ – N mineralization during 98-day incubation period

Medium	Treatment	DAY3	DAY7	DAY14	DAY28	DAY49	DAY98
River sand	CONTROL	2.73 ^{cdef}	0.09 ^j	0.14 ^g	0.36 ^g	0.17 ^{fg}	0.10 ^g
	PM	2.49 ^{ef}	1.12 ^{hi}	1.33 ^f	1.54 ^f	0.55 ^{efg}	0.20 ^{fg}
	N:P:K	5.71 ^b	3.53 ^f	5.23 ^e	5.25 ^c	0.74 ^{ef}	0.28 ^{fg}
	PM + N:P:K	3.07 ^{cde}	1.60 ^g	1.90 ^f	4.40 ^d	1.00 ^e	0.21 ^{fg}
	BIOCHAR	1.70 ^{fg}	0.18 ^j	0.17 ^g	0.13 ^g	0.05 ^g	0.01 ^g
	BIOCHAR + PM	1.10 ^g	1.46 ^{gh}	1.41 ^f	1.58 ^f	0.58 ^{efg}	0.24 ^{fg}
	BIOCHAR + N:P:K	2.64 ^{def}	0.92 ⁱ	1.36 ^f	0.48 ^g	1.05 ^e	0.33 ^{fg}
	BIOCHAR + PM + N:P:K	3.99 ^c	4.16 ^{de}	1.87 ^f	5.50 ^c	2.94 ^c	0.79 ^{de}
Top soil	CONTROL	3.91 ^{cd}	4.73 ^c	5.05 ^e	3.91 ^d	0.74 ^{ef}	0.27 ^{fg}
	PM	5.76 ^b	6.15 ^b	10.06 ^c	6.54 ^b	7.75 ^a	2.71 ^a
	N:P:K	7.27 ^a	4.99 ^c	14.80 ^a	2.67 ^e	2.29 ^d	1.23 ^c
	PM + N:P:K	7.25 ^a	6.98 ^a	9.19 ^d	5.52 ^c	3.95 ^b	1.08 ^{cd}
	BIOCHAR	3.89 ^{cd}	4.75 ^c	4.94 ^e	3.84 ^d	1.99 ^d	1.24 ^c
	BIOCHAR + PM	5.98 ^b	4.57 ^{cd}	8.94 ^d	5.43 ^c	4.09 ^b	1.93 ^b
	BIOCHAR + N:P:K	3.92 ^{cd}	3.77 ^{ef}	12.37 ^b	9.69 ^a	1.84 ^d	0.52 ^{ef}
	BIOCHAR + PM + N:P:K	6.47 ^{ab}	7.38 ^a	8.40 ^d	7.17 ^b	2.24 ^d	0.81 ^{de}

Means followed by the same letter in each column are not significantly different from each other ($P>0.05$)

This could be attributed to ammonia volatilization (Meissinger and Jokela, 2000) from soil amended with N:P:K compared to poultry manure with slow releasing nutrient potentials. On the other hand, NO_3^- - N release during the 98-days incubation period from River sand was significantly higher compared to that of Top soil and the average amount of NO_3^- - N released was the highest at 3 DAI from river sand compared to top soil throughout the duration of the study. N:P:K from river sand release was significantly higher than every other interaction in the study from 1 DAI to 98 DAI, which showed that NO_3^- - N mineral in N:P:K 15:15:15 is readily available compared to all other amendments in the study (Tables 5 and 6) and the general decrease in NO_3^- - N concentration from 14 DAI to 98 DAI could be attributed to leaching (Tom 2002; Marco *et al.*, 2002). NO_2^- - N mineral in the soil amendments were available in lower concentrations compared to NH_4^+ - N and NO_3^- - N. The rate of NO_2^- - N release was higher in top soil compared to river sand throughout the 98 days incubation period and it was at 3 DAI that the highest values were recorded. NO_2^- - N release just like NO_3^- - N was available in N:P:K more than all other amendments till 28 DAI but a significantly higher value was recorded from poultry manure at 49 DAI compared to all other

amendments used in the study (Tables 7 and 8). The low NO_2^- - N contents in soil applied with NPK fertilizer from 28 - 98 DAI compared with 14 DAI could be attributed to acidic properties of NPK fertilizer, because acidity reduces soil microbial activity and this would in turn reduce nutrient mineralization (Xu *et al.*, 2002).

CONCLUSION

The use of Top soil for raising seedlings increases the release of NH_4^+ - N while River sand increases the release of NO_3^- - N. The application of N:P:K 15:15:15 would stimulate microbial activities for early release of NH_4^+ - N from the Top soil, but Poultry Manure will in the long run sustain a continuous NH_4^+ - N release to the plant. N:P:K 15:15:15 in combination with poultry manure is also recommended for use, when NO_3^- - N mineral is required for Noni production in river sand at nursery stage.

RECOMMENDATION

It is recommended that poultry manure be used for soil amendment for Noni production in top soil to sustain the release of NH_4^+ - N and NO_2^- - N mineral to the plant over a longer period of time.

Table 6: The effect of growth medium and amendment on NO₃ – N mineralization during 98-days incubation period

Factor	LEVEL	DAY 1	DAY3	DAY7	DAY14	DAY28	DAY49	DAY98
Amendment	River sand	0.54	0.93 ^a	0.88 ^a	0.44	0.30 ^a	0.28 ^a	0.24 ^a
	Top soil	0.49	0.82 ^b	0.72 ^b	0.42	0.18 ^b	0.20 ^b	0.20 ^b
	CONTROL	0.49 ^b	0.51 ^f	0.53 ^f	0.14 ^f	0.06 ^f	0.05 ^e	0.05 ^f
	PM	0.53 ^b	0.84 ^c	0.69 ^d	0.30 ^e	0.12 ^e	0.18 ^c	0.24 ^d
	N:P:K	0.63 ^a	1.39 ^a	1.23 ^a	1.18 ^a	0.66 ^a	0.58 ^a	0.43 ^a
	PM + N:P:K	0.50 ^b	1.00 ^b	0.77 ^c	0.46 ^c	0.29 ^b	0.32 ^b	0.33 ^b
	BIOCHAR	0.50 ^b	0.73 ^d	0.60 ^e	0.10 ^g	0.06 ^f	0.04 ^e	0.03 ^f
	BIOCHAR + PM	0.50 ^b	0.89 ^c	0.76 ^c	0.27 ^e	0.22 ^d	0.26 ^d	0.24 ^d
	BIOCHAR + N:P:K	0.50 ^b	0.97 ^b	1.12 ^b	0.61 ^b	0.25 ^c	0.18 ^c	0.17 ^e
	BIOCHAR + PM + N:P:K	0.46 ^b	0.66 ^e	0.69 ^d	0.40 ^d	0.25 ^c	0.31 ^b	0.29 ^c
Interaction								
M	X	A	0.045	0.048	0.033	0.03	0.01	0.014

Means followed by the same letter in each column are not significantly different from each other ($P>0.05$)

Table 7: Influence of growth medium with amendment on NO₃ – N mineralization during 98-days incubation period

Medium	Treatment	DAY 1	DAY3	DAY7	DAY14	DAY28	DAY49	DAY98
River sand	CONTROL	0.47 ^{cde}	0.55 ^{gh}	0.59 ^e	0.09 ^{hi}	0.06 ⁱ	0.02 ^l	0.01 ^k
	PM	0.55 ^{bc}	0.80 ^{de}	0.62 ^e	0.14 ^{gh}	0.11 ^h	0.16 ^h	0.20 ^{fg}
	N:P:K	0.75 ^a	1.78 ^a	1.76 ^a	1.74 ^a	1.10 ^a	0.93 ^a	0.65 ^a
	PM + N:P:K	0.50 ^{cd}	0.77 ^e	0.81 ^c	0.19 ^{fg}	0.25 ^{cd}	0.25 ^d	0.26 ^e
	BIOCHAR	0.55 ^{bc}	0.82 ^{de}	0.57 ^e	0.03 ⁱ	0.06 ⁱ	0.06 ^k	0.05 ^j
	BIOCHAR + PM	0.52 ^{bc}	0.80 ^{de}	0.71 ^d	0.28 ^e	0.26 ^c	0.32 ^c	0.32 ^{cd}
	BIOCHAR + N:P:K	0.61 ^{bc}	1.29 ^b	1.42 ^b	0.75 ^b	0.34 ^b	0.24 ^{de}	0.21 ^f
	BIOCHAR + PM + N:P:K	0.37 ^e	0.65 ^{fg}	0.58 ^e	0.27 ^e	0.25 ^{cd}	0.24 ^{de}	0.25 ^e
Top soil	CONTROL	0.52 ^{bc}	0.47 ^g	0.48 ^f	0.19 ^{fg}	0.06 ⁱ	0.09 ^j	0.08 ⁱ
	PM	0.51 ^{bc}	0.89 ^{de}	0.76 ^{cd}	0.47 ^d	0.14 ^g	0.20 ^{fg}	0.29 ^d
	N:P:K	0.52 ^{bc}	1.01 ^c	0.71 ^d	0.61 ^c	0.23 ^d	0.23 ^{ef}	0.21 ^f
	PM + N:P:K	0.50 ^{bcd}	1.23 ^b	0.72 ^d	0.73 ^b	0.33 ^b	0.39 ^b	0.40 ^b
	BIOCHAR	0.46 ^{cde}	0.65 ^{fg}	0.63 ^e	0.16 ^{gh}	0.06 ⁱ	0.02 ^l	0.02 ^{jk}
	BIOCHAR + PM	0.49 ^{cd}	0.97 ^{cd}	0.82 ^c	0.25 ^{ef}	0.19 ^e	0.19 ^g	0.17 ^g
	BIOCHAR + N:P:K	0.40 ^{de}	0.64 ^{fg}	0.82 ^c	0.47 ^d	0.16 ^f	0.13 ⁱ	0.12 ^h
	BIOCHAR + PM + N:P:K	0.55 ^{bc}	0.67 ^f	0.80 ^c	0.52 ^d	0.26 ^c	0.39 ^b	0.34 ^c

Means followed by the same letter in each column are not significantly different from each other ($P>0.05$)

Table 8: The effect of growth medium and amendment on NO₂ – N mineralization during 98-days incubation period

Factor	LEVEL	DAY 1	DAY3	DAY7	DAY14	DAY28	DAY49	DAY98	
Medium									
	River sand	0.016	0.019 ^b	0.043	0.15 ^b	0.13 ^b	0.10 ^b	0.11	
	Top soil	0.011	0.028 ^a	0.065	0.18 ^a	0.14 ^a	0.16 ^a	0.14	
Amendment									
	CONTROL	0.006	0.009 ^e	0.019 ^d	0.060 ^d	0.049 ^f	0.073 ^f	0.105	
	PM	0.027	0.023 ^d	0.039 ^{cd}	0.065 ^d	0.089 ^d	0.267 ^a	0.217	
	N:P:K	0.017	0.033 ^b	0.103 ^a	0.474 ^a	0.306 ^a	0.198 ^b	0.119	
	PM + N:P:K	0.012	0.039 ^a	0.059 ^{bc}	0.156 ^c	0.138 ^d	0.121 ^d	0.214	
	BIOCHAR	0.01	0.012 ^e	0.017 ^d	0.022 ^d	0.021 ^g	0.020 ^g	0.013	
	BIOCHAR + PM	0.01	0.020 ^d	0.030 ^{cd}	0.043 ^d	0.059 ^e	0.105 ^e	0.102	
	BIOCHAR + N:P:K	0.013	0.029 ^c	0.086 ^{ab}	0.320 ^b	0.252 ^b	0.156 ^c	0.125	
	BIOCHAR + PM + N:P:K	0.011	0.021 ^d	0.081 ^{ab}	0.169 ^c	0.170 ^c	0.121 ^d	0.114	
Interaction									
M	X	A	Ns	0.003	0.02	0.03	0.01	0.005	Ns

Means followed by the same letter in each column are not significantly different from each other (P>0.05)

Table 9: Influence of growth Medium with Amendment on NO₂ – N mineralization during 98-days incubation period.

Medium	Treatment	DAY3	DAY7	DAY14	DAY28	DAY49
River sand	CONTROL	0.01 ^h	0.01 ^d	0.09 ^e	0.06 ⁱ	0.09 ^g
	PM	0.02 ^d	0.04 ^d	0.07 ^{ef}	0.11 ^h	0.15 ^f
	N:P:K	0.05 ^b	0.11 ^{ab}	0.48 ^a	1.10 ^a	0.25 ^b
	PM + N:P:K	0.02 ^{def}	0.02 ^d	0.04 ^{ef}	0.25 ^{cd}	0.07 ^h
	BIOCHAR	0.01 ^{gh}	0.01 ^d	0.02 ^f	0.06 ⁱ	0.01 ^k
	BIOCHAR + PM	0.01 ^{fgh}	0.02 ^d	0.02 ^{ef}	0.26 ^c	0.05 ⁱ
	BIOCHAR + N:P:K	0.03 ^c	0.12 ^{ab}	0.41 ^b	0.34 ^b	0.14 ^f
	BIOCHAR + PM + N:P:K	0.01 ^{efg}	0.02 ^d	0.04 ^{ef}	0.25 ^{cd}	0.05 ⁱ
Top soil	CONTROL	0.01 ^{efg}	0.02 ^d	0.03 ^{ef}	0.06 ⁱ	0.06 ⁱ
	PM	0.03 ^c	0.03 ^d	0.06 ^{ef}	0.14 ^g	0.38 ^a
	N:P:K	0.02 ^d	0.10 ^{abc}	0.47 ^{ab}	0.23 ^d	0.15 ^{ef}
	PM + N:P:K	0.06 ^a	0.10 ^{bc}	0.27 ^{cd}	0.33 ^b	0.17 ^d
	BIOCHAR	0.02 ^{def}	0.02 ^d	0.03 ^{ef}	0.06 ⁱ	0.03 ^j
	BIOCHAR + PM	0.03 ^c	0.04 ^d	0.06 ^{ef}	0.19 ^c	0.16 ^c
	BIOCHAR + N:P:K	0.03 ^c	0.06 ^{cd}	0.23 ^d	0.16 ^f	0.17 ^d
	BIOCHAR + PM + N:P:K	0.03 ^c	0.14 ^a	0.30 ^c	0.26 ^c	0.19 ^c

Means followed by the same letter in each column are not significantly different from each other (P>0.05)

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