Scientific Research Publishing

Agricultural Sciences, 2023, 14, 1547-1560
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Carbon and Nitrogen Mineralisation of a Lixisol in South Sudan Zone of Burkina Faso

Abdramane Sanon[1,2*], Alain P. K. Gomgnimbou[1], Kalifa Coulibaly[2], Fidele K. Zongo[3], Tièro-Wè Chris Julius Dabire[4], Wilfiried Sanou[2], Hassan B. Nacro[2]

[1]Centre National de la Recherche Scientifique et Technologique (CNRST), Institut de l'Environnement et de Recherche Agricole (INERA), Laboratoire Sol-Eau-Plante (SEP), Station de Farako-Bâ, Bobo-Dioulasso, Burkina Faso
[2]Laboratoire d'étude et de recherche sur la fertilité du sol (LERF), Institut du Développement Rural (IDR), Université Nazi Boni, Bobo-Dioulasso, Burkina Faso
[3]Centre universitaire de Tenkodogo, Université Thomas Sankara, Ouagadougou, Burkina Faso
[4]Unité de Formation et de Recherches en Sciences de la Vie et de laTerre, Université Joseph KI-Zerbo, Ouagadougou, Burkina Faso
Email: *sdumba8006@gmail.com

Abstract

In today's environment where agriculture needs to produce sustainably, local fertilizer resources must be encouraged to achieve multiple crop performance and environmental goals. The purpose of this study was to investigate the effects of combined inputs of biowaste and inorganic fertilisers on the mineralization of carbon and nitrogen of a Lixisol under continuous upland rice growing conditions. To this end, agronomic trials were set up in 2018 and 2019, using a Fisher randomized complete block design with 6 treatments and four replications at Farako-bâ research station. The treatments were: T1 (Control), T2 (NPK + Urea), T3 (7500 kgha of Chicken droppings); T4 (7500 kg/ha of chicken droppings + 100 kg/ha of urea); T5 (7500 kg/ha of chicken droppings + 500 kg/ha of Burkina Phosphate); T6 (7500 kg/ha of chicken droppings + 500 kg/ha of Burkina Phosphate + 100 kg/ha of urea). Highest respirometry was observed in treatments T3, T4 and T6 and treatment T4 significantly increased the mineralization coefficient by 15% after 21 days of incubation. T4 and T6 resulted in increases in ammonium ion of 74.15% and 100%, respectively, compared to the control. Likewise, treatments T4 and T6 resulted in a significant increase in nitrate ion of 104.83 and 103.25%, respectively. Biowaste combined with inorganic fertilizers may have a capacity to improve the availability of leachate nutrients under upland rice conditions.

Keywords

Bio-Waste, Rice, Carbone, Nitrogen and Mineralisation

How to cite this paper: Sanon, A., Gomgnimbou, A.P.K., Coulibaly, K., Zongo, F.K., Dabire, T.-W.C.J., Sanou, W. and Nacro, H.B. (2023) Carbon and Nitrogen Mineralisation of a Lixisol in South Sudan Zone of Burkina Faso. *Agricultural Sciences*, **14**, 1547-1560.
https://doi.org/10.4236/as.2023.1411100

Received: March 1, 2023
Accepted: November 13, 2023
Published: November 16, 2023

1. Introduction

In Burkina Faso, the decline in cereal crop yields is a reflection of declining soil fertility and unstable climatic conditions [1]. Chemical and physical poverty leading to loss of nutrients and organic matter reserves is the major cause of reduced agricultural production [2]. Soil organic matter content (SOM) is the main indicator of fertility, due to its impact on soil chemical, physical and biological properties [2]. SOM increases aeration and water holding capacity, provides habitat for soil organisms that feed the nutrient cycle, conserves and provides essential nutrients for crop productivity [3]. Organic matter inputs maintain or replenish soil organic matter reserves [4] [5] and improve the physico-chemical properties of soils, which results in direct and indirect effects on crop growth and yield [6]. Thus, ensuring more stable and sustainable soil productivity helps to reduce producers' dependence on external inputs such as mineral fertilizers [7]. Often, farmers use mineral fertilisers to compensate the lack of organic matter such as manures in their farms [8]. However, those mineral fertilisers are not always accessible due to the price or availability [9]. Previous studies showed that the effects of organic manures on soils in Sub-Saharan Africa do not last for long due to rapid decomposition [10]. In addition, the use of inorganic fertilisers also has its own downside, including soil acidity, leaching of nutrients, weakening of soil structure [11]. Therefore, there is a need to improve approaches of sustainable soil fertility management in Sub-Saharan Africa in general and Burkina Faso in particular.

In this context, the use of integrated crop-livestock systems should be encouraged, as they have been shown to improve the cyclical uptake of nutrients in pasture, cropland and fattened livestock in the barn [12]. Crop-livestock integration contributes to improving the economic performance of farms while maintaining soil fertility and reducing their exposure to risks such as feed shortage [13]. However, most of the studies on crop-livestock integration have focused on large animals that can provide not only farm labour (ploughing, transport) but also a lot of manure at the level of barns and improved pastures [14]. Poultry, for example, has not been sufficiently taken into account in the research on crop-livestock integration. Yet, poultry droppings account for between 26.46% and 35.72% of organic manure production, and contribute to fertilising nearly 4.50% of the total cultivated area of farms in Burkina Faso [15]. Furthermore, studies by [16] showed that poultry manure was particularly rich in nitrogen ($N = 2.58\%$) and total phosphorus ($P = 2.73\%$), compared to cattle dung ($N = 1.96\%$ and $P = 0.96\%$), goat dung ($N = 1.61\%$ and $P = 1.06\%$) and sheep dung ($N = 2\%$ and $P = 0.90\%$). According to [17], poultry manure releases nitrogen faster than livestock manure when applied to soil. What are effects of bio-waste on the carbon mineralisation coefficient and nitrogen mineralisation are scarce in Burkina Faso. The objective of this study is twofold: firstly, to study the synergistic influence of bio-waste and mineral fertilisers on carbon mineralisation and the carbon coefficient, and secondly, to study the effect of this combination on the nitrogen mineralisation of a leachate under upland rice growing conditions in the south Sudan zone of Burkina Faso. The importance of this work is to contribute to the valorisation of locally available bio-waste and Burkina phosphate in order to improve the yield of upland rice while reducing production costs.

2. Material and Methods

Plant material and fertilisers

The rice variety used was FKR59 (WAB 99-84), originating from the Campinas Agricultural Institute in Sao Paulo (Brazil). It has 95 - 100 days duration from sowing to maturity with a potential yield of 5000 kg/ha [18]. The seeds used for the study were offered by the rice breeding Programme at Farako-ba Research Station. Chicken droppings were obtained from poultry farms located in the peri-urban area of Bobo Dioulasso. Compost was produced at the experimental station. Burkina Phosphate was obtained from the Regional Directorate of Agriculture of the Hauts-Bassins region, and mineral fertilisers (NPK = 14-23-14 and Urea = 46% N) were purchased locally from retailers. Chicken manure with N = 3.09%; total Phosphore = 2.56 $mg \cdot kg^{-1}$ of soil; total Potassium = 1.43 $mg \cdot kg^{-1}$; C/N = 12.33); Compost (N = 2.18%; total Phosphore = 0.026 $mg \cdot kg^{-1}$; total Potassium = 1.8 $mg \cdot kg^{-1}$; C/N = 10.79); Burkina Phosphate with: P_2O_5 = 25.38%; CaO = 34.45%; MgO = 0.27% Ferral = 6.5%; SiO_2 26.24%.

Experimental design and trial implementation

The trial was set up in a Fisher randomised complete block design with 6 treatments (**Table 1**) and 4 replications. The fertilisation treatments were each applied to 9 m^2 plot. The recommended mineral fertilisation of 200 kg/ha of NPK (14-23-14) was applied 14 days after sowing, and 100 kg/ha of urea (46% N) applied in two instalments: 35% of the dose (35 kg/ha) at 30 days after sowing and 65% of the dose (65 kg/ha) at 45 days after sowing. Rice straw compost (5000 kg/ha) and Burkina Phosphate (500 kg/ha) were applied 5 days before sowing. Chicken droppings at a rate of 7500 kg/ha were split, with two-thirds of the rate (5000 kg/ha) applied 5 days before sowing and one-third of the rate (2500 kg/ha) applied 45 days after sowing. Rice seeds were sown at 0.20 m × 0.20 m spacing. The same operation was repeated each year. Land preparation consisted of clearing and flat ploughing. At the time of ploughing, the straws were buried and harrowing was carried out immediately afterwards. **Table 2** shows the chemical content of the soil and chicken droppings. Carbon Mineralisation For carbon mineralisation, the respirometric test was used. The purpose of this test is to assess the biodegradation and mineralisation capacity of soils. We used the design described by [19] and adapted by [20]. This method makes it possible to measure the mineralisation of organic matter incorporated into the soil on a daily basis during an incubation period by measuring the carbon of the released carbon dioxide (C_CO_2). The major innovation in this study was the use this method under upland rice production with chicken droppings. To do this, soil samples were taken before sowing. Carbon dioxide dosage was performed

Table 1. List of treatments applied during the trial.

T1: Control without manure: N-P-K (0-0-0)
T2: NPK + Urea: N-P-K (74-46-28)
T3: Chicken droppings: N-P-K (231.75-192-107.25)
T4: Chicken droppings + Urea: N-P-K (277.75-192-107.25)
T5: Chicken droppings + Burkina Phosphate: N-P-K (231.75-318.9-107.25)
T6: Chicken droppings + Burkina Phosphate + Urea: N-P-K (277.75-318.9-107.25)

Table 2. Soil particles and chemical content of the soil, poultry manure and compost.

	Parameters	Soil	Chicken Droppings
Granulometry (%)	Clay	11.55	-
	Silt	14.84	-
	Sands	73.6	-
Chemical Parameters	pH_H_2O	5.43	6.91
	OM (%)	0.95	37.6
	N_total (%)	0.053	3.09
	C/N	10.36	12.33
	P_total (mg·kg^{-1})	95.6	2.56
	P_ass (mg·kg^{-1})	2.54	
	K_total (mg·kg^{-1})	937.81	1.43
	K_dispo (mg·kg^{-1})	47.80	-
	CEC (Cmol.kg^{-1})	1.72	-
	SBE (Cmol.kg^{-1})	1.01	-
	Saturation rate (%)	59.03	-

N_Total: Total Nitrogen; C/N: Carbon/Nitrogen ratio; P_Total: Total Phosphorus, K_Total: Total Potassium; OM: Organic Matter; SBE: exchangeable bases; CEC: Cation Exchange Capacity.

according to the technique recommended by [21] with minor modifications. Soil samples were dried under shelter (shade) and sieved to 2 mm. Subsequently 100 g of soil moisturised with two-thirds field capacity was placed in hermetically sealed one-litre jars containing a C-CO_2 trap, consisting of 10 ml of 0.1 N caustic soda and a flacon of water to moisten the ambient environment. A control was used per replicate, consisting of one flacon containing only soda and another containing only distilled water. Controls were placed under the same conditions to account for the initial carbonisation of the soda in the jar and blocking errors. To maintain the same temperature for the duration of the incubation, the jars were kept in an oven at 31.5˚C. The C-CO_2 released is determined daily by colorimetry for three weeks, using 0.1 N hydrochloric acid and phenol phthalein (colour indicator) [22]. At the time of dosing, barium chloride ($BaCl_2$) is used to avoid the fixation of atmospheric CCO_2 by the soda exposed in the beaker. If Q1 represents the quantity of HC1 (ml), N/10 used for the control jars and Q2 the quantity of HC1 N/10 used for the jars containing the moistened soil, the weight P in mg of CO_2 released per 100 g of soil is given by the formula of [22]:

$$P = (Q1 - Q2) \times 2.2 \quad (1)$$

As 2.2 g of CO_2 corresponds to 1 ml of HCI N/10.

Carbon mineralisation Coefficient

The soil carbon mineralisation coefficient is defined as the percentage of carbon that can be mineralised as CO_2 under certain conditions.

The carbon mineralisation coefficient is that proposed by [22]:

$$\frac{C\_CO_2}{C} = \frac{C\_CO_2}{C\_Total} \times 100 \quad (2)$$

where C_CO_2 represents the quantity expressed in mg of carbon of carbon dioxide released in seven days for a 100 g sample of soil under the defined experimental conditions; C-total represents the total carbon determined by the method of [23] and is also expressed in mg per 100 g of soil.

In situ mineralisation of nitrogen

We used the in situ neat nitrogen mineralisation method adapted from [24], which consisted of in situ soil incubation followed immediately by mineral nitrogen extraction. The principle of which is as follows: a soil sample was reincorporated in a polyvinyl chloride cylinder, fitted with a lid at the top and a very fine mesh at the bottom to prevent leaching and disturbance by soil fauna. The sample was then placed back into the sample hole in situ and left in place for a fortnight. The results of in situ nitrogen mineralisation enable an approximate quantification of neat mineralisation and neat ammonification during a crop cycle. It is hypothesised that this net mineralisation represents the main source of plant available nitrogen that is likely to be lost. The evolution of mineral N during the period considered (a complete crop cycle of rice under upland rice conditions) was studied. The monitoring was carried out in six situations with a 15-days interval. Mineral nitrogen was monitored over a 5-weeks (75-day) incubation period with 2 dosages every two weeks. The mineral nitrogen was extracted by 1 M potassium chloride (KCl) solution before and after two weeks of incubation. In each of the six elementary plots (Control, NPK + Urea, CD, CD + Urea, CD + BP, CD + BP + Urea) two incubation cylinders were placed in order to obtain a better coverage. This design enables the description of the "dynamics" of $N\_NH_4^+;\ NO_3^-$ in the soil from the results of the mineral nitrogen dosage in the successive samples, the measurement of the ammonification rate and, as consequence, the net ammonification in situ. Thus, the following parameters can be calculated 1) the mineralization of organic matter in the soil under upland rice, disregarding nitrogen inputs by rain, symbiotic fixation and losses by volatilization, leaching, erosion and denitrification, 2) the mineralization in the presence of mineral fertilizer, 3) the mineralisation in the presence of Chicken droppings alone, 4) the mineralization in the presence of Chicken droppings, Natural Phosphate (Burkina phosphate) and Urea. Three samples were taken from the time of planting to maturity: 45, 60 and 70 days after sowing, respectively.

Statistical analyses

Data arrangement and calculation of averages were conducted in Excel 2013 (Microsoft Office). Then, the different variables measured were further analysed, to assess the significance of the effect of combined inputs of bio-wastes and inorganic fertilisers on these parameters. An analysis of variance was performed using Gentstat Discovery version 11.1. The Fisher test (LSD) was used for comparison of means when the ANOVA revealed significant differences between treatments at the 5% probability level [25].

3. Results

Induced effects of bio-waste and mineral fertilizers on carbon mineralization

Table 3 shows the respired C_CO$_2$ relative to the treatments during incubation. The analysis of variance shows a significant difference between treatments for carbon mineralisation (C_CO$_2$ breathed). In 2018, on day 1, day 7, day 14 and day 21, the highest respirometry was observed in treatments CD + BP + Urea, CD and CD + Urea, which were significantly higher than the other treatments. In 2019, the respirometry was identical for treatments CD, CD + Urea and CD + BP. The highest respirometry was recorded with treatment CD + BP + Urea. Treatments control and NPK + Urea presented the lowest respirometry on day 1, day 7, day 14 and day 21 of incubation. The coefficients of carbon mineralisation before sowing showed significant differences between treatments at days 1, 7, 14 and 21 of incubation, respectively (**Table 4**). In 2018, a decrease in carbon coefficient was noticed for all treatments. The mineralization coefficient in treatment NPK + Urea decreased from 1.029 on the 1st day of incubation to 0.03 on the 21st day, i.e. a reduction rate of 96%. The carbon mineralisation coefficient decreased from 0.066 on the first day of incubation to 0.043 on the 21st day of incubation, i.e. a reduction of 62% in the treatment CD + BP + Urea. In 2019, the T4 treatment CD + Urea recorded the best carbon mineralisation coefficients regardless of the incubation time. At 21 days of incubation, treatment CD + Urea resulted in an increase in carbon mineralisation coefficient of 15%, compared with treatment T1 (Control). The carbon mineralisation coefficients were significantly higher than those recorded for the NPK + Urea treated soils. Treatment-induced effects on soil nitrogen mineralisation.

Treatment-induced effects on ammonium (NH_4^+)

The statistical analysis showed significant differences between treatments for ammonium content at 45 and 60 days (**Figure 1**). On the other hand, at 75 days, there were highly significant differences between treatments for ammonium

Table 3. C_CO$_2$ respired (mg C 100·g^{-1}·sol) of treatments during incubation before sowing.

Treatments	Years							
	2018				2019			
	1st day	7th day	14th day	21st day	1st day	7th day	14th day	21st day
Control	4.4 ± 1.18^{a,b}	14.14 ± 3.82^{a}	17.49 ± 4.06^{a,b}	19.58 ± 4.36^{a}	7.625 ± 0.28^{a,b}	62.55 ± 0.23^{a,b}	99.83 ± 0.54	127.95 ± 0.62
NPK + Urea	2.84 ± 0.37^{c,d}	10.87 ± 4.3^{ab}	14.69 ± 6.7^{a,b}	18.51 ± 8.74^{a,b}	7.450 ± 0.26^{b}	61.92 ± 0.33^{b}	99.2 ± 0.75	127.72 ± 1.28
CD	4.099 ± 0.2^{b,c}	12.77 ± 0.7^{a}	17.7 ± 0.8^{a,b}	20.57 ± 0.92^{a}	7.825 ± 0.21^{a,b}	62.82 ± 0.8^{a,b}	100.28 ± 0.84	128.82 ± 0.67
CD + Urea	5.64 ± 0.4^{a}	14.71 ± 1.43^{a}	19.64 ± 1.81^{a}	24.4 ± 0.48^{a}	7.675 ± 0.4^{a,b}	62.8 ± 0.73^{a,b}	100.28 ± 1.25	128.15 ± 0.87
CD + BP	2.09 ± 0.8^{d}	7.27 ± 1.32^{b}	9.14 ± 0.84^{b}	11.3 ± 2.21^{b}	7.800 ± 0.26^{ab}	62.95 ± 0.9^{a}	99.75 ± 1.42	128.07 ± 1.45
CD + BP + Urea	4.83 ± 0.27^{a,b}	14.07 ± 1.81^{a}	20.44 ± 2.58^{a}	23.22 ± 2.81^{a}	7.97 ± 0.17^{a}	63.22 ± 0.53^{a}	100.3 ± 0.71	128.6 ± 1.08
F pr.	<0.0001	0.03	0.01	0.03	0.01	0.01	0.55	0.7
Significance	****	*	*	*	*	*	NS	NS

CD: Chicken Droppings; BP: Burkina Phosphate; F pr.: F Probability; NB: treatments with the same letter in the same column are not significantly different; NS: Non Significant; * = significant at 5%; **** = significant at 0.01%.

Table 4. Carbon mineralisation coefficients before sowing per incubation period.

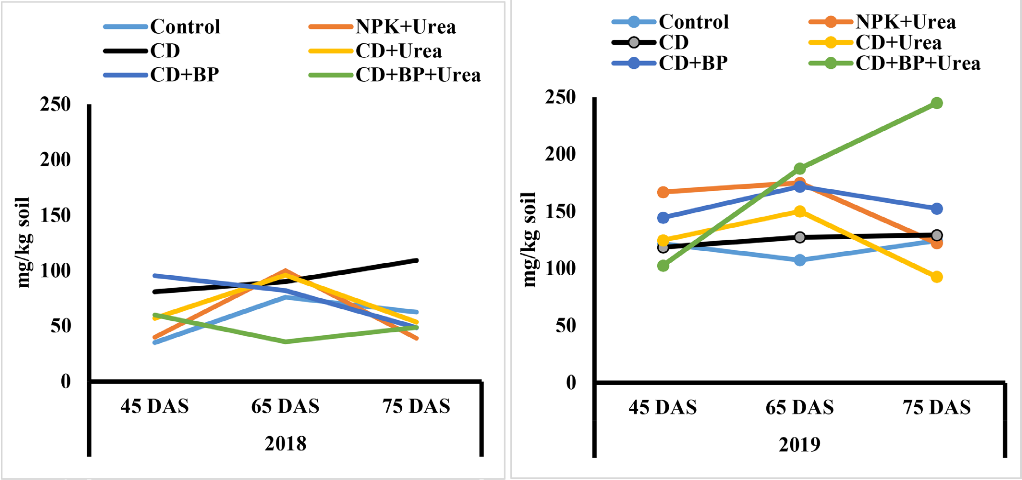
Traitements	Years							
	2018				2019			
	1st day	7th day	14th day	21st day	1st day	7th day	14th day	21st day
Témoin	1.038 ± 0.07^{a}	0.03411 ± 0.00247^{a}	0.043 ± 0.021	0.04724 ± 0.00341^{a}	0.015 ± 0	0.12 ± 0.03	0.22 ± 0.05	0.25 ± 0.05
NPK + Urea	1.029 ± 0.03^{a}	0.02235 ± 0.00147^{b}	0.029 ± 0.009	0.03806 ± 0.00251^{b}	0.016 ± 0	0.13 ± 0.03	0.27 ± 0.02	0.27 ± 0.07
CD	0.922 ± 0.05^{a,b}	0.02704 ± 0.00227^{b}	0.034 ± 0.01	0.04355 ± 0.00365^{a}	0.016 ± 0.01	0.13 ± 0.05	0.21 ± 0.05	0.26 ± 0.09
CD + Urea	0.898 ± 0.07^{b}	0.02773 ± 0.00144^{b}	0.033 ± 0.01	0.04601 ± 0.00240^{a}	0.017 ± 0.01	0.13 ± 0.05	0.21 ± 0.05	0.28 ± 0.1
CD + BP	0.863 ± 0.055^{b}	0.02668 ± 0.00289^{b}	0.037 ± 0.005	0.04475 ± 0.00485^{a}	0.015 ± 0	0.12 ± 0.03	0.22 ± 0.04	0.25 ± 0.05
CD + BP + Urea	0.662 ± 0.01^{c}	0.02641 ± 0.00164^{b}	0.028 ± 0.01	0.04360 ± 0.00271^{a}	0.015 ± 0.01	0.11 ± 0.05	0.2 ± 0.05	0.23 ± 0.1
F pr.	<0.001	<0.001	0.73	0.008	0.678	0.97	0.45	0.97
Significance	***	***	*NS*	**	*NS*	*NS*	*NS*	*NS*

CD: Chicken Droppings; BP: Burkina Phosphate; F pr.: F Probability; NB: treatments with the same letter in the same column are not significantly different; NS: Non-significant; * = significant at 5%; ** = significant at 1%; *** = significant at 0.1%.

content. In 2018, treatment CD had the highest ammonium content. Compared with the control, 10 treatment CD resulted in 74.15% increase in ammonium ion. However, in 2019, the ammonium-nitrogen value remained constant. On the other hand, in 2019, on the 75th day after sowing, treatment CD + BP + Urea had the highest ammonium-nitrogen value. Treatment CD + BP + Urea led to an increase in ammonium-nitrogen of 100% and 60% compared to treatment Control and treatment NPK + Urea, respectively.

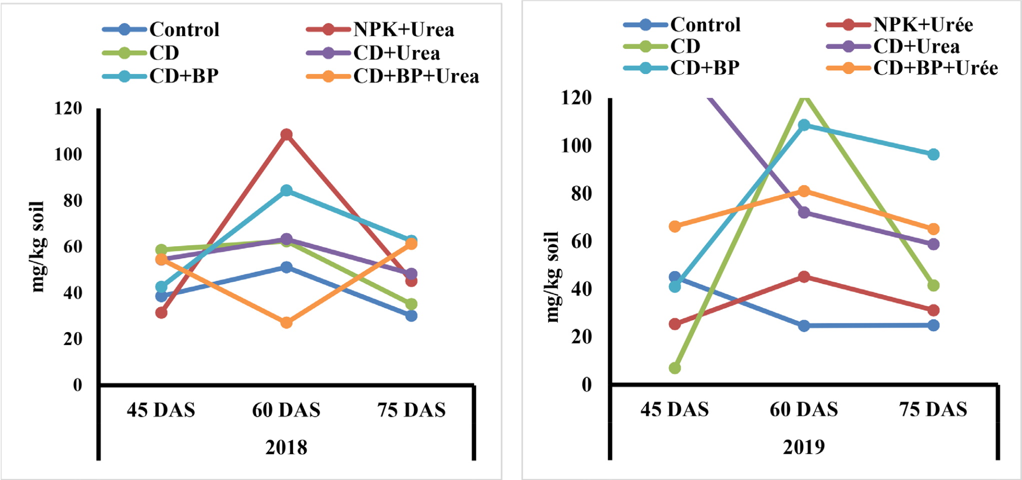
Treatment-induced effects on nitric nitrogen (NH_3^+)

Statistical analysis showed significant differences between treatments for nitrate ion at 45 and 60 DAS, respectively. However, at 75 DAS, there were highly significant differences ($P < 0.001$) between treatments for nitrate ion content (Figure 2). In 2018, at 45 DAS, treatment CD resulted in 46.72% increase in nitrate ion compared with treatment NPK + Urea. At 60 days, treatment NPK + Urea presented the best nitrate ion content followed by treatments CD and CD + Urea. During this stage, treatment NPK + Urea resulted in 112.24% increase in nitrate ion relative to treatment T1 (control) and 29.01% relative to treatment CD + Urea. However, at 75 DAS, the control had the lowest nitrate ion content. Treatment T5 (CD + BP) caused the highest nitrate ion values and resulted in an increase in nitrate ion levels of 104.83% relative to the control. Treatment (CD + BP was followed by treatment CD + BP + Urea which resulted in 103.25%



CD: Chicken Droppings; BP: Burkina Phosphate.

Figure 1. Evolution of ammonium nitrogen over the treatments' incubation time in 2018 and 2019.



CD: Chicken Droppings; BP: Burkina Phosphate.

Figure 2. Evolution of nitric nitrogen over the treatments' incubation period (2018-2019).

increase in nitrate ion compared to the control. In 2019, it was observed that the four fertiliser treatments NPK + Urea, CD, CD + BP and CD + BP + Urea, produced similar nitric nitrogen over time, and the maximum value was reached at 60 DAS with 20 the CD treatment. In 2019, nitrification due to treatment CD + Urea reached a maximum at 45 DAS before decreasing steadily from 60 days. Conversely, treatment Control experienced a drop in nitrate nitrogen at 60 days before increasing at a constant rate from 75 days.

4. Discussion

Treatment-induced effects on carbon mineralisation

The results obtained in carbon mineralisation have enabled a better understanding of some mechanisms governing the dynamics of organic matter in soils under upland rice cultivation subjected to different levels of organic and mineral fertilisers. Throughout the incubation period of the samples, the labile carbon mineralisation rate remained positive. At 21 days of incubation, the increase in the carbon mineralisation coefficient due to treatment Chicken droppings + Urea was comparable to those obtained previously on Ferralsols and Areinosols located in the western part of the south sudan zone [26] and Lixetsols and Cambisols in the northern Sudanian zone [27]. The low rates of carbon mineralisation in Lixisols and clayey soils resulted from a better protection of organic fractions by clays [27]. The mineralization rate is significantly lower than those obtained (92%) by [28] on a silty-clay soil amended with a minimal amount of crop residues (soil + rape). Our results are in line with those of [22] who showed that fallow and worm fertilizer slow down the carbon mineralization coefficient. According to this author, figures below 0.5 are found in very pronounced hydromorphic soils, which explains the accumulation of organic matter, and between these two extremes are the non-leached ferruginous soils. The work of [29] showed that the CO_2 flux increases with the increase in the dose of organic matter applied to soils with a sandy-loam texture, which is poor in organic matter. According to the work of [30], poultry manure enhances C-CO_2. This is due to the increase in labile carbon resulting from exogenous organic matter serving as the main energy carrier for microorganisms. However, the treatments with chicken manure plus Burkina Phosphate stopped the rate of C-CO_2 emission, indicating that the contribution of CD + BP to C-CO_2 emission is negligible compared to soils amended with Chicken droppings and NPK + urea. Furthermore, textural characteristics and temperature play an important role on the C-CO_2 accumulation and carbon mineralisation coefficient [30]. From these authors it appears that the higher the sand/clay ratios, the lower the values of C-CO_2. This situation explains the low values of Coefficient of mineralisation obtained, as the granulometric analysis of the soils in the trial had a sand/clay ratio equal to 8.40. These results show that during a crop cycle, the level of total organic carbon in the soil increases with time. This carbon storage would take place through the increase in root biomass on the one hand, and through the percolation of above-ground organic matter on the other. This study thus confirms the existence of pools of organic matter in lixisols that have different functions and dynamics depending on their size and degree of decomposition [26]. These results indicate a good availability of nitrogen. Similar results were observed by [31]. Cultivation causes mineralisation of soil organic matter. This explains the rapid mineralisation of organic manure treatments. According to [28], organic inputs influence the mineralising power of soils, assessed by the mineralisation of carbon and nitrogen and reflecting the biological activity in the soil. Therefore, mineralisation of organic carbon is proportional to the organic matter content of the soil. It has been shown that the fine soil fraction is prone to the mineralisation processes [32]. Similar observations were made in Farako-ba under upland rice growing condition, with sandy silty texture soil. This elucidates the high mineralization observed in this soil Treatment-induced effect on the mineralisation of soil nitrogen. The results of in situ nitrogen mineralisation showed that ammonification occurs during the crop cycle of upland rice. The study of in situ nitrogen mineralisation indicates that $N\_NH_4^+$ dynamics is characterised by five phases in irrigated rice [33]. The differences between the situations are rather related to the quantities of ammonium that vary according to the sampling date and treatments. In upland rice with chicken droppings, similar results were observed with three phases. Compared to the control, treatments Chicken droppings + Urea and Chicken droppings + Phosphate Burkina + Urea resulted in an increase in nitrate ion of 107 and 103% respectively. This increase in nitric nitrogen is attributable to the mineralisation of organic matter following exogenous inputs of organic substrates. Similar observations were made by [31] using biochard. The best effect of nitrogen mineralisation was observed with soil treatments with chicken manure (low C/N), due to its relative richness in nitrogen and elements that are easily broken down. At maximum tillering (60 DAS), mineral nitrogen production of 91 and 68 mg/100g soil was observed under chicken manure for NH_4^+ and NO_3^- respectively. These values are significantly higher than those obtained by [34], who reported, after 56 days of incubation, a production of mineral nitrogen (NH_4^+ and NO_3^-) of 12.66 and 7.85 mg/100g of soil respectively for non-saline sandy soil and saline sandy soil amended with poultry manure. This reveals the beneficial effect of organic input to the sandy soils where the nitrification process is otherwise low. After 75 days of incubation, the higher amount of mineralised nitrogen obtained with chicken droppings. This is due to the fact that organic residues with a low C/N ratio are easily mineralised by the soil microflora and release significant amounts of mineral nitrogen [35]. Nitrogen mineralisation is more important in sandy texture than in fine texture. The results of the work of [35] showed that sandy and silty soils have higher specific respiration and mineralisation rates than clayey soils and that the higher the sand/silt ratio (S/L), the higher the specific respiration. This ratio showed a value of 5 for the site under investigation. This shows that there are other factors that influence the intensity of nitrogen mineralisation; since the soil in the present study had the highest mineralisation rates. According to [36] experimentally showed that some calcareous soils in Morocco mineralise significant amounts of nitrogen compared to Fersiallitic and Isohumic Vertisols. The low mineralisation rate recorded under the conditions of this trial may then be due to the presence of limestone in the soil, leading to a stimulation of the mineralisation of soil organic nitrogen.

The results showed that biowaste and inorganic fertilizers contributions had allowed an improvement in the chemical characteristics of the soil. Indeed, the increases by compared to unmanured soil are on average + 0.32 units for pH_water. The results obtained have shown that the Chicken Droppings + urea lead to a significant increase in OM by 0.94%, resulting in a positive modification of microbiological activity

5. Conclusion

This work is a contribution to soil fertility improvement by adding biowaste to soils lacking organic matter, as mineral fertilisers are not always affordable. The study showed that on 60 DAS, mineral fertilizers (NPK + Urea) provided higher nitrate ion (NO_3^-) and ammonium (NH_4^+) compared to the control by 112.24% and 32.58%, respectively. At 75 DAS, relative to the control, treatment Chicken droppings resulted in an increase of ammonium ion (NH_4^+) of 74.15% and treatment Chicken droppings + Urea resulted in an increase of nitrate ion (NO_3^-) of 104.83%. These results indicated that the T4 treatment Chicken droppings + Urea caused an increase of the mineralization coefficient by 15% after 21 days of incubation. The combination of mineral fertilizer with chicken droppings would improve soil fertility. This study paves the way for the valorisation of locally available bio-waste, which can reduce the costs of rice production. Studies on the use of these materials in field crops and their mixing with mineral fertilisers (Phosphate of Burkina and urea) are necessary before the dissemination of this technology to farmers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Bationo, A., Koala, S. and Ayuk, S.E. (1998) Fertilité des sols pour la production céréalière en zone soudano-sahélienne et valorisation des phosphates naturels. *Cahiers Agricultures*, **7**, 365-371.

[2] Robertson, G.P., Gross, K.L. and Hamilton, S.K. (2014) Farming for Ecosystem Services: An Ecological Approach to Production Agriculture. *BioScience*, **64**, 404-415. https://doi.org/10.1093/biosci/biu037

[3] Brady, N.C. and Weil, R.R. (2007) The Nature and Properties of Soils. 14th Edition, Prentice Hall, Upper Saddle River.

[4] Segda, Z., Bonzi, M. Gnankambary, Z. Lompo, F. and Sedogo, P.S. (2014) Influence of Soil Fertility Management on Organic Carbon Mineralization in Irrigated Rice. *Journal of Agricultural and Crop Research*, **2**, 32-43.

[5] Ouattara, A., Koulibaly, B., Dakuo, D., Coulibaly, K., Bazongo, P., Traore, O. and Nacro, H.B. (2021) Effects of Direct Sowing under Mulch-Based Cropping System (DMC) on Cotton and Maize Yield and Chemical Characteristics of Ferruginous Soil (Lixisoil) in the South Sudan Area of Burkina Faso. *Open Journal of Soil Science*, **11**, 352-365. https://doi.org/10.4236/ojss.2021.116018

[6] Faisal, M., Imran, K., Umair, A., Tanvir, S., Sabir, H., Muhammad, S., Muhammad, A. and Sami, U. (2017) Effects of Organic and Inorganic Manures on Maize and Their Residual Impact on Soil Physico-Chemical Properties. *Journal of Soil Science and Plant Nutrition*, **17**, 22-32.

[7] Hatfield, J.L., Sauer, T.J. and Cruse, R.M. (2017) Soil: The Forgotten Piece of the Water, Food, Energy Nexus. *Advances in Agronomy*, **143**, 1-46.

[8] Awopegba, M., Segun Oladele, S. and Awodun, M. (2017) Effect of Mulch Types on Nutrient Composition, Maize (*Zea mays* L.) Yield and Soil Properties of a Tropical Alfisol in Southwestern Nigeria. *Eurasian Journal Soil Science*, **6**, 121-133. https://doi.org/10.18393/ejss.286546

[9] Oladele, O., Adeyemo, A., Awodun, M., Ajayi, A. and Fasina, A. (2019) Effects of Biochar and Nitrogen Fertilizer on Soil Physicochemical Properties, Nitrogen Use Efficiency and Upland Rice (*Oryza sativa*) Yield Grown on an Alfsol in Southwestern Nigeria. *International Journal of Recycling of Organic Waste in Agriculture*, **8**, 295-308. https://doi.org/10.1007/s40093-019-0251-0

[10] Glaser, B., Lehmann, J. and Zech, W. (2002) Ameliorating Physical and Chemical Properties of Highly Weathered Coils in the Tropics with Charcoal—A Review. *Biology and Fertility of Soils*, **35**, 219-230. https://doi.org/10.1007/s00374-002-0466-4

[11] Barrow, C.J. (2012) Biochar: Potential for Countering Land Degradation and for Improving Agriculture. *Applied Geography*, **34**, 21-28. https://doi.org/10.1016/j.apgeog.2011.09.008

[12] Larwanou, M. and Saadou, M. (2011) The Role of Human Interventions in the Treedynamics an Environmental Rehabilitation in the Sahel Zone of Niger. *Journal of Arid Environment*, **75**, 194-200. https://doi.org/10.1016/j.jaridenv.2010.09.016

[13] Vall, E., Koutou, M., Blanchard, M., Coulibaly, K., Diallo, M.A. and Nadine, A. (2012) Intégration agriculture-élevage et intensification écologique dans les systèmes agro-sylvo-pastoraux de l'Ouest du Burkina Faso, province du Tuy. *Actes du séminaire*, Bobo-Dioulasso, Novembre 2011, 13.

[14] Uwah, D.F., Ukoha, G.O. and Iyango, J. (2012) Okra Performance and Soil and Water Conservation as Influenced by Poultry Manure and Organic Mulch Amendments. *Journal of Food Agriculture &Environment*, **1**, 748-754.

[15] Coulibaly, K., Sankara, F., Pousga, S., Philippe, J., Nacoulma, P.J. and Nacro, B.H. (2018) Pratiques avicoles et gestion de la fertilité des sols dans les exploitations agricoles de l'Ouest du Burkina Faso. *Journal of Applied Biosciences*, **127**, 12770-12784. https://doi.org/10.4314/jab.v127i1.2

[16] Gomgnimbou, A.P.K., Nacro, H.B., Sanon, A., Sedogo, P.M. and Martinezv, J. (2014) Observed Effects of the Animal Manure Application Practices on the Chemical Parameters and Status of Lixisols in the South Soudanian Zone (Bobo-Dioulasso, Burkina Faso). *Journal of Biodiversity and Environmental Sciences*, **1**, 214-227.

[17] Kiba, D.I., Zongo, N.A., Youssouf, O., Traoré, A., Louré, M., Barry, H., Sanon, S., Bassirou, S., Gnankambary, Z., Ouandaogo, N., Lompo, F. and Sedogo, M.P. (2020) Poultry Farming Practices Affect the Chemical Composition of Poultry Manure and Its C and N Mineralization in a Ferric Acrisol. *Journal of Agricultural Science*, **12**, 95-104. https://doi.org/10.5539/jas.v12n3p95

[18] INERA (2016) Programme Riz et Riziculture, Fiche technique de la variété de riz FKR59 (WAB99-84), Institut National de l'Environnement et des Recherches Environnementales-Station Farako-Ba, Bobo-Dioulasso.

[19] Morel, J.L., Jacquin, F., Guxkert, A. and Barthel, C. (1979) Contribution à la réalisation de tests de détermination de la maturité des composts urbains. Ministère de l'Environnement et Cadre de Vie, 26.

[20] Sedogo, P.M. (1993) Evolution des sols ferrugineux tropicaux lessivés sous culture: incidence des modes de gestion sur la fertilité. Master's Thesis, Université Nationale de Côte d'Ivoire, Abidjan.

[21] Blachère, H. and Villecourt, P. (1956) Etude de l'absorption d'oxygène par les sols. Comptes 15 rendus du VI^e congres international de la Science du Sol.

[22] Dommergues, Y. (1960) La notion de minéralisation de carbone. *Agronomie Tropicale*, **15**, 54-60.

[23] Walkley, A. and Black, J.A. (1934) An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method. *Soil Science*, **37**, 29-38. https://doi.org/10.1097/00010694-193401000-00003

[24] Bonzi, M. (2002) Évaluation et déterminisme du bilan de l'azote en sols cultivés du centre Burkina Faso: Étude par traçage isotopique 15N au cours d'essais en station et en milieu paysan. Master's Thesis, Ecole Nationale Supérieure D'Agronomie et des Industries Alimentaire, Vandoeuvre-lès-Nancy.

[25] Gomes, F.P. (2009) Curso de estatística Experimental. 15th Edition, FEALQ, Piracicaba.

[26] Pallo, F.J.P., Sawadogo, N., Sawadogo, L., Sedog, P.M. and Assa, A. (2008) Statut de la matière organique des sols dans la zone sud-soudanienne au Burkina Faso. *Biotechnology, Agronomy, Society and Environment*, **212**, 291-301.

[27] Pallo, J.P.F., Sawadogo, N., Zombre, N.P. and Sedogo, M.P. (2009) Statut de la matière organique des cambisols et des lixisols sous formations naturelles de longue durée en zone nord-soudanienne au Burkina Faso. *Agronomie Africaine*, **21**, 215-229. https://doi.org/10.4314/aga.v21i3.56444

[28] Bouajila, K., Ben Jeddi, F., Taamallah, H., Jedidi, N. and Sanaa, M. (2014) Effets de la composition chimique et biochimique des résidus de cultures sur leur décomposition dans un sol Limono Argileux du semi-aride. *Journal of Materials and Environmental Science*, **5**, 159-166.

[29] Mancer, H., Bettiche, F., Chaib, W., Dekki, N., Benaoun, S. and Rechachi, M.Z. (2020) Influence de la salinité des eaux d'irrigation sur la minéralisation du carbone organique dans le sol. *Journal Algérien des Régions Arides*, **14**, 48-55.

[30] Koulibaly, B., Dakuo, D., Traoré, O., Ouattara, K. and Lompo, F. (2017) Long-Term Effects of Crops Residues Management on Soil Chemical Properties and Yields in Cotton-Maize-Sorghum Rotation System in Burkina Faso. *Journal of Agriculture and Ecology Research*, **10**, 1-11. https://doi.org/10.9734/JAERI/2017/31178

[31] Ding, Y., Liu, Y., Liu, S., Li, Z., Tan, X., Huang, X., Zeng, G., Zhou, L. and Zheng, B. (2016) Biochar to Improve Soil Fertility. A Review. *Agronomy for Sustainable De-*

velopment, **36**, Article No. 36. https://doi.org/10.1007/s13593-016-0372-z

[32] Segda, Z., Louis, P., Yameogo, P.L., Sine, M., Bado, B.V. and Mando, A. (2014) Nitrogen Use Efficiency by Selected NERICA Varieties in Burkina Faso. *African Journal of Agricultural Research*, **9**, 1172-1179. https://doi.org/10.5897/AJAR2013.8383

[33] Segda, Z. (2006) Gestion de la fertilité du sol pour une production améliorée et durable du riz (*Oryza sativa* L.) au Burkina Faso: Cas de la plaine irriguée de Bagré. Master's Thesis, Université de Ouagadougou, Ouagadougou.

[34] Oustani, M. (2006) Contribution à l'étude de l'influence des amendements organiques (fumier de volailles et fumier de bovins) sur l'amélioration des propriétés microbiologiques des sols sableux non salés et salés dans les régions Sahariennes (Cas de Ouargla). Thèse de l'Université de Kasdi Merbah, Ouargla.

[35] Elherradi, E., Soudi, B. and Elkacemi, K. (2003) Evaluation de la minéralisation de l'azote de deux sols amendés avec un compost d'ordures ménagères. *Etude et Gestion des Sols*, **10**, 139-154.

[36] Soudi, B., Chiang, C.N. and Zeraouli, M. (1990) Variations saisonnières de l'azote minéral et effet combiné de la température et de l'humidité du sol sur la minéralisation. Actes Institut. *Agronomiques Véterimaires*, **10**, 29-38.