

Original research

## **Carbon, Nitrogen, Sulfur, and Phosphorus Mineralization from Sugarcane Residues in Clay Soils**

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### **Abstract:**

For a total of 90 days, two incubation experiments were conducted to study the mineralization of C, N, P and S form clay soil treated by sugarcane residues. The first experiment involved incubating soil samples at 30 °C to study the emission of CO<sub>2</sub> from organic residues, which included determining the amount of mineralized C, and another trail involved incubating soil samples at room temperature to study the other elements using 4 different organic residues [bagasse (B), filter cake (FC), boiler ash (BA), and dry sugarcane leaves (DSL)]. The findings demonstrated that the highest C emission was 232.5 and 225.0 mg C kg<sup>-1</sup> of soil treated with B and DSL, respectively, when compared to other organic wastes. The maximum daily C emission for soil amended with B and DSL was 10.7 and 10.2 mg C / kg soil / day, respectively at the 5th day of incubation. N mineralization from all amendments added to the soil showed a decrease at the beginning of the incubation period and then increased with increasing incubation period until the end of the incubation. At the conclusion of the incubation period, P mineralization in the soil increased with all treatments as compared to the control treatment. The maximum daily mineralization rate of P was 5.08 mg P kg soil / day on the first day of incubation for the soil treated with BA. Also, S mineralization increases in the first incubation periods, and then decreased with increasing incubation periods in soils treated with all organic wastes.

**Keywords:** Mineralization; Bagasse; Filter mud cake; Boiler ash; Dry sugarcane leaves and clay soil.

### **1- Introduction**

Recently, increasing population requires an increase in agricultural production, which has led to the use of expensive chemical fertilizers in developing countries to increase agricultural production. Therefore, it is necessary to go towards supplementing chemical fertilizers with organic fertilizers, especially from the recycling of organic waste through organic fertilization. Egypt is a country with abundant organic residual resources, particularly sugarcane residues. In Egypt's south, specifically in governorates of El-Minya, Sohag, Qena, Luxor, and Aswan, sugarcane is mostly grown. Each year, this crop generates more than 16.8 million tons of wastes from sugarcane (Hamada, 2011 and Sweed, 2019).

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During manufacturing processes of sugar from sugarcane, huge amounts of by-products are released, such as bagasse, filter mud, and boiler ash (**Sardar et al., 2012**). According to **El-Haggag and El-Gowini, (2005)**, of these residues, 30% are bagasse (2,797,562 tons), 3.5% filter cake (315,854 tons) and 0.4% boiler ash (36,098 tons). The composting process for sugarcane residues is very important to increase soil fertility and increase its nutrients content by mineralizing these nutrients (**Salman et al., 2023**). Compost is one of the most popular organic fertilizers used in the soil as a source of carbon and nutrients that are released into the soil due to the process of mineralization of organic wastes (**Teutscherova et al., 2017**). In general, the addition of organic residues to soil act as amendments that improve the physical, chemical and biological properties of the soil (**Kalembasa and Kalembasa, 2016**). Large amounts of carbon dioxide emissions come out of the soil as a result of the decomposition of organic waste (**Paustian et al., 2000**). This emission of CO<sub>2</sub> emitted from the mineralization of organic waste can cause a change in the Earth's geochemical cycle and climate change, which is known as the greenhouse effect (**Chen et al., 2010**). The risks of CO<sub>2</sub> emissions continue for 1000 years after stopping and reducing them, leading to a positive improvement in the environment (**Solomon et al., 2009**), which affects many environmental systems as well as human health through the spread of many diseases (**WHO, 2003**). From this, To guarantee the safe addition of organic wastes to increase soil fertility, the soil's organic carbon dynamics must be observed. (**Parraga-Aguado et al., 2017; Sweed and Negim, 2019 and Negim and Sweed, 2020**).

Organic residues, when added to the soil, are microbially decomposed (**Berg 2000**) known as the process of mineralization (**Wu and Brooks 2005**). And it is evidence of soil fertility (**Castro-Bustamante and Hartz 2016**). Mineralization process contributes to the circulation of nutrients in the soil such as carbon, nitrogen, phosphorus and sulfur. The microorganisms present in the soil are the ones that carry out the mineralization process, and the amount of nutrients released depends on the characteristics and chemical composition of the organic waste (**Khalil et al. 2005 and Abbasi et al. 2015**). Also, **Martens, (2000)** explained a close correlation between the chemical composition of plant organic waste and its rate of decomposition and accumulation as humus in soil. Thus, humus is mainly rich in C and some other nutrients such as N. According to **Azim et al. (2018)** the decomposition of organic waste varies according to the nature of its origin and to C:N ratio. Moreover, mineralization rate increases with increase of N content of organic wastes. Also, there are abiotic environmental factors that control the mineralization of organic waste, such as temperature (**Curiel-Yuste et al. 2007 and Wang et al. 2013**), and soil moisture (**Craine and Gelderman 2011**).

The process of nitrogen mineralization is biological. The amount of nitrogen released to crops is determined by the physical, chemical, and biological characteristics of soil microbes (**Manojlovic et al. 2010**) as well as the chemical composition of organic matter (e.g., N content, carbon: N ratio, and contents of cellulose and hemicelluloses, lignin, and polyphenols) (**Mohanty et al. 2011**). High N content and low C:N ratio organic amendments mineralize enough N to support plant growth (**Cordovil et al., 2005**). On the other hand, in organic agriculture (OA) with lower N contents and greater C:N ratios, N can be immobilized (**Manojlovic et al. 2010**).

**Naher et al. (2004)** found that after applying organic manure for 15 days, the P mineralization increased gradually over time. **Sultana et al. (2021)** showed that the highest S mineralization was 313.48 mg/kg for soil treated with a mixture of municipal solid waste, mustard oil cake, and sugarcane pressing clay at 7 days of incubation period.

This research aims to study the mineralization rate of different sugarcane residues in clay soil, by following up the emission of CO<sub>2</sub> from the soil incubated at a 30 °C for different periods up to 90 days, and following up the mineralization of nitrogen, phosphorus, and sulfur, the extent of potassium release, and the change in the content of the incubated soil of organic matter.

## 2-Materials and Methods

### 2.1.Sampling sites of soil and sugarcane residues

Soil sample used in this incubation trials was collected from the surface layer (0–15 cm) of Arab Kima, Abu Sunaid Village, Kom Ombo Center (latitude 24°33'655"N, longitude 32°56'717"E), Aswan Governorate, Egypt. The sugarcane residues namely bagasse (B), filter cake (FC) and boiler ash (BA) were collected from Kom-Ombo sugar factory located in Kom Ombo (24°48'281"N, 32°94'066"E), while dry sugarcane leaves (DSL) was obtained from the same the field which soil sample was collected. Soil and residues samples were prepared at Laboratory of Soil Chemical Analyses, faculty of Agriculture and Natural Resources, Aswan University. Soil sample was air-dried, ground and passed through a sieve (2 mm). All sugarcane residues were washed by distilled water, dried in air then oven dried at 70 °C, ground and passed through a sieve (1 mm). The soil and sugarcane residue properties were estimated according to the procedure of **Cottenie et al., (1982)** and **Klute, (1986)** and the data are shown in Table 1 and 2.

**Table 1.** Physico-chemical characteristics of studied soil.

Properties	Unit	Value
pH (1 : 2.5, soil : water ratio)		8.40
**EC (1:5, soil: water ratio)	dS m <sup>-1</sup>	0.40
Bulk density	g cm <sup>-3</sup>	1.65
Particle density	g cm <sup>-3</sup>	2.40
Porosity	%	31.25
Organic carbon	%	1.15
Organic Matter	%	2.00
Total CaCO <sub>3</sub>	%	2.70
SP*	%	41.10
Particle size distribution		
Sand	%	43
Silt	%	13
Clay	%	44
Texture	Clay	
Available N	mg kg <sup>-1</sup>	90.00
Available P	mg kg <sup>-1</sup>	21.31
Available S	%	0.052
Total N	%	0.19
Total P	mg kg <sup>-1</sup>	19.31
Total S	%	0.14

\*SP= Saturation percentage and \*\*EC= Electrical conductivity

**Table 2: Chemical properties of organic residues used.**

Parameter	OC (%)	Total N (%)	C:N ratio	Total P (mg kg <sup>-1</sup> )	Total K (%)	Total S (%)
Baggase	77.81	0.33	235.79	35.9	0.063	0.62
Filter cake	42.27	1.26	33.55	146.0	0.168	0.48
Boiler ash	13.45	0.42	32.02	124.0	0.149	1.28
Dry sugarcane leaves(DSL)	67.24	0.28	240.14	37.0	0.079	0.45

## 2.2.Experiments

### a- Carbon emission

Incubation trial of soil with or without organic residues was carried out to study carbon emission for 90 days at 30 °C in incubator. The dried organic residue was added separately to the soil at rate of 0.5% based on dry weight of each residue, the mixture was moisten at field capacity (60 %, WHC). Three replications were applied in a completely random block design within five treatments as follows.

- T1: soil without organic residues (as a control).
- T2: soil + B
- T3: soil + FC
- T4: soil + BA
- T5: soil + DSL

A 100 g from air-dried soil was taken in a 200ml plastic bottle. A small tube containing 10 mL of 1N NaOH was placed in each bottle. The bottles were tightly closed and incubated at 30 °C using an incubator (POL-EKO-AP ARATURA SP.J.). CO<sub>2</sub> evolution readings were taken at 0, 3, 5, 10, 20, 30, 60 and 90 days by titration with 1 N HCL in the presence of methyl orange for all incubation periods (Gaur et al., 1971).

### b- Mineralization of nitrogen, phosphorus and sulfur

Mineralization of N, P and S were studied by incubating the soil samples at room temperature with same organic materials and same design used in carbon mineralization trial. The dried organic residues were added to the soil in an amount equal to 0.5% based on dry weight of each residue separately, at 60 % of WHC (field capacity). A 400 g of dried soil were placed in the circular plastic boxes. They were incubated for periods of 1, 5, 10, 15, 30, 60, 75 and 90 days. After completion of each incubation period, the incubated soil at each period was air-dried, ground and passed through a sieve (2 mm) and N, P, S and organic matter were estimated according to these methods.

- Available nitrogen extraction from incubated soil was carried out with 0.5 M of K<sub>2</sub>SO<sub>4</sub> and was estimated by Kjeldahl distillation (Gerhardt VAP200), according to Jackson, (1973).
- Available phosphorus extraction was performed from incubated soil with a 0.5 M NaHCO<sub>3</sub> solution at pH 8.5, and estimated by spectrophotometer (Pg instruments UV/VIS spectrometer T80), according the procedure of Murphy and Riley (1962).
- Soluble sulphates were precipitated in incubated soil with barium chloride solution (Jackson, (1973).

- Organic matter content in incubated soil was estimated using Welkley–Black method as described by Nelson and Sommers (1996).

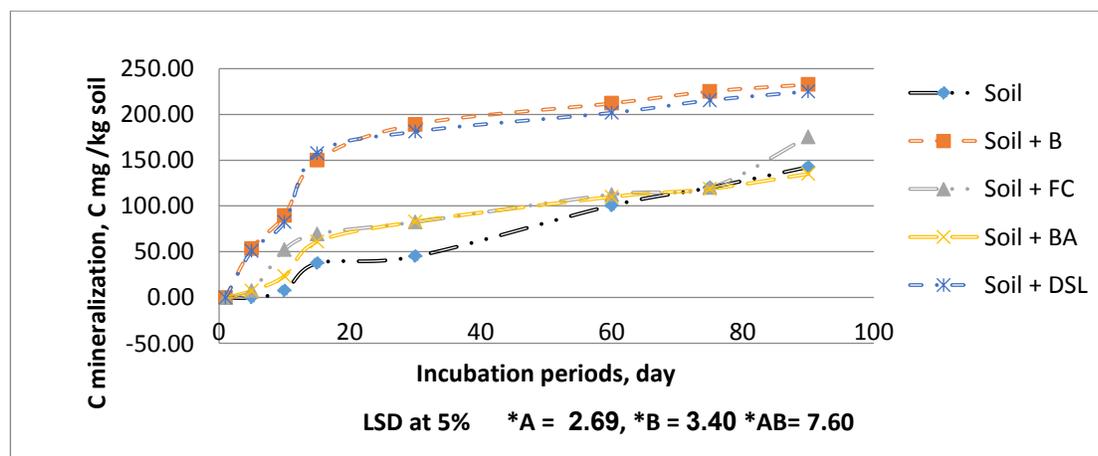
### 2.3. Statistical analysis

Using Microsoft Excel 2010, a two-way analysis of variance (ANOVA) was used to compare the statistical significances of the various treatments. To find the differences between the treatments and their interactions, the least significant differences (LSD) at the 5% level of probability were calculated.

## 3-Results and Discussion

### 3.1. Carbon emission (CE)

In general, the emission of CO<sub>2</sub> (mg C kg<sup>-1</sup> soil) results from microbial activity resulting from their respiration and decomposition of organic wastes. The results in Fig. 1 showed that, the carbon emission (CE) of different sugarcane residues in the incubated soil was significantly higher than in the untreated soil, regardless of the incubation period. Carbon release pattern from different soil conditioners was in the following order, B > DSL > FC > BA. The maximum CE of the incubated soil were as follows, 232.5, 225.0, 175.5, 142.5 and 135.0 mg C kg<sup>-1</sup> soil in treated and untreated soil with B, DSL, FC, control and BA, respectively at the final day of the incubation period, i.e. 90 days. Also, CE increases with the increase of the incubation periods with all residues up to 90 days.



\*A = Organic residues (bagasse, pressing mud, boiler ash and dry sugarcane leaves)

\*B = Incubation period (1, 5, 10, 15, 30, 60, 75 and 90 day).

\*AB = Interaction between organic residues and incubation periods

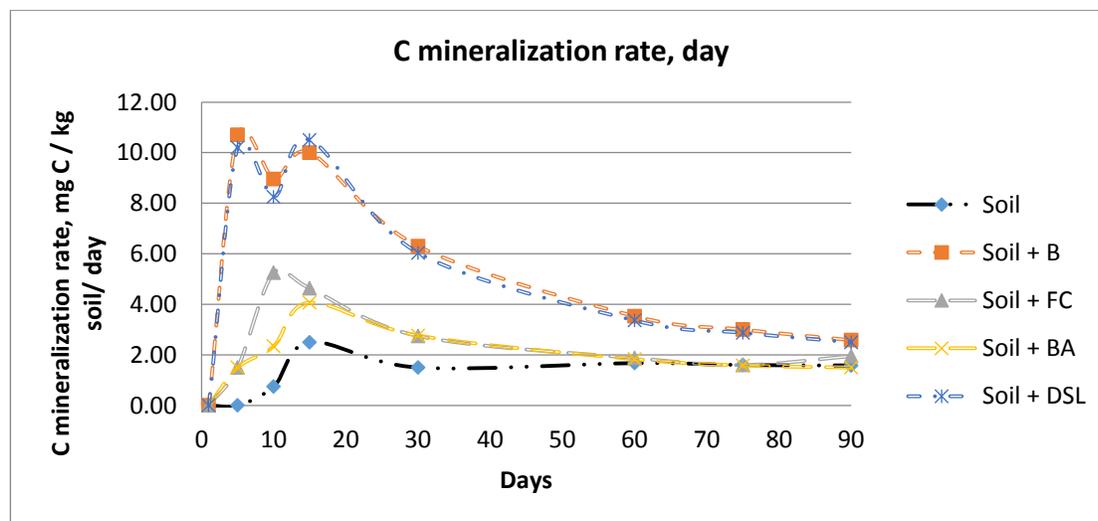
**Fig. 1. Carbon mineralization in untreated and treated soils with organic residues during the incubation period.**

Moreover, the CE process for the different residues started in 5 days, except for the untreated soil, the emission of its organic matter that it previously contained began after 10 day of the start of incubation process. These findings are in support of Mishra et al. (2016). Also, data showed that, on the 5th day of incubation period, the CE of both the soil treated with B and DSL were higher compared to other treatments, and this increase is probably due to the high B content of sugar that resulted during the pressing of sugarcane in the factory, which acted as a source of carbohydrates for microorganisms. Which led to an increase in the activity of microorganisms, and thus an increase in the amount of carbon released, and close to this reason, an increase in the

released carbon appeared with the soil treated with DSL, compared to the other wastes. This interpretation is confirmed by **Silva et al. (2017)**. In general, decomposition and carbon release at the beginning of the incubation periods were low and then increased. Perhaps that is because at the beginning of the incubation, the number of microbes were less and their activity was low, then with the increase of the incubation period the decomposition increased because of increased microbial number, which led to an increase in CE. In general, a significant relationship was found between various organic residues and the incubation period in soil for CE.

Data in Fig. 1 also showed at beginning of the incubation periods, an increasing increase in the rate of CE with all additives to the incubated soil was recorded, then a decreasing increase with the increase in the incubation periods. On the other hand, the higher rate of CE with the two treatments of B and DSL compared to BA and FC, which means that the addition of the first two amendments will cause an increase in the concentration of CO<sub>2</sub> in the atmosphere, which increases the effect of the greenhouse in the environment, while the other two amendments work to mitigate this effect. According to **Silva et al. (2017)** showed that sugarcane bagasse content is higher in sugar and alcohol compared to the rest of the organic sugarcane waste, which may increase microbial attack and cause more CO<sub>2</sub> emission. The interaction of various organic residues and incubation periods in soil amended for CE was significant.

Fig. 2 showed the daily emission rate of the residues under study. In general, the highest daily emission rate was with B and DSL treated soils compared to the other treatments and the control. However, increase in CE was recorded after 5<sup>th</sup> days of incubation with incubated soils by B and DSL. The biggest value was 10.7 mg C kg<sup>-1</sup> day<sup>-1</sup> with the soil treated with B at the 5<sup>th</sup> day of the incubation process, followed by the soil treated with DSL at the 15<sup>th</sup> day from the beginning of the incubation, which amounted to 10.5 mg C kg<sup>-1</sup> day<sup>-1</sup>.



**Fig. 2 Daily carbon mineralization rate in soil untreated and treated with organic residues (mg kg<sup>-1</sup>).**

Moreover, the daily emission rate of C was high in the first periods of incubation and decreased with increasing incubation days, and this trend appeared with all treatments and controls. Perhaps this is because the used organic waste contains easily oxidized substances that decompose first, then complex substances that require a longer time for decomposition. While, easily oxidized substances content are low in both FC and BA. Therefore, the oxidation rate is lower compared to

the other treatments. This may be due to microbial decomposition of newly added organic residues in the soil which developed more CO<sub>2</sub> upon oxidation, and thus more carbon was mineralized. **Paul and Solaiman (2002)** have reported more CM from with organic residues in incubated soil than from the control.

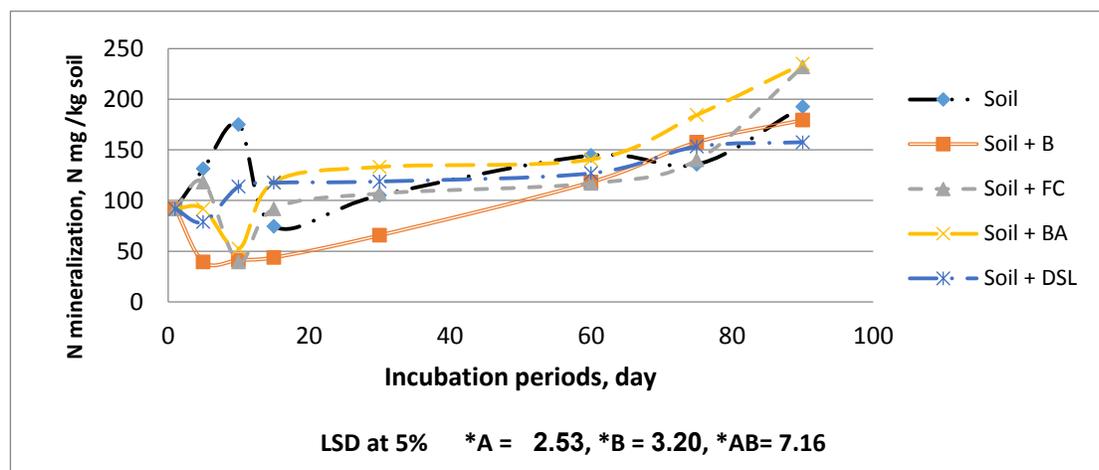
#### **a- Nitrogen mineralization (NM)**

Throughout the incubation period, the concentration of available N (mg N kg<sup>-1</sup> soil) rose in all organic treatments (Fig. 3). In the control treatment, the content ranged between 74.12 and 192.60 mg N kg<sup>-1</sup> soil, while all treatments under study; It ranged between 39.39 and 234.87 mg N kg<sup>-1</sup> soil. Also, the results illustrated that, the NM was constant on the first day of the incubation process, perhaps this is because the microorganisms have not been active yet, but on the 5<sup>th</sup> day of incubation, the rate of NM increased significantly in the untreated soil (control) and the treated soils with FC, while the treated soil with BA did not change, and the NM decreased with the soil treated with B and DSL compared to the original soil. In general, NM decreased at beginning of the incubation process and then increased with the increase in the incubation periods, where it reached to the maximum values at the end of the incubation (90 days) with the treatments of B, BA and DSL. As for the NM of the untreated soil (control) and the soil treated with FC, it gave high values at the beginning of the incubation period compared to other treatments and then decreased. Data also in Fig. 3 showed that, the maximum values of NM at 90 days of incubation were 234.87, 231.99, 192.60, 179.46 and 157.58 mg N kg<sup>-1</sup> soil for treated soil with BA, FC, control, B and DSL, respectively. The data also showed that. the minimum values for mineralized N release differ from one treatment with an organic amendment to another and from one incubation time to another. They were 74.41 mg N kg<sup>-1</sup> soil (day 15), 39.39 mg N kg<sup>-1</sup> soil (day 5), 39.39 mg N kg<sup>-1</sup> soil (day 10), 52.53 mg N kg<sup>-1</sup> soil (day 10) and 78.75 mg N kg<sup>-1</sup> soil (day 5) of soil untreated, B, FC, BA and DSL, respectively. These results are consistent with those obtained (**Masunga et al. 2016 and Awad and Sweed, 2020**) for NM in soils treated with organic waste.

Due to the presence of high molecular weight compounds in organic residues, slow microbial decomposition may have contributed to the slow rate of NM. Later, as microbial activity and population increased as a result of obtaining C and nutrients from organic wastes, the rate of microbial decomposition speeded up. After a particular amount of time, microorganisms used up all of the available C and nutrients, and NM reduced as a result of the decline in microbial population. According to findings reported by **Adeiran et al. (2003) and Abbasi et al. (2015)** these, NM rose with an increase in incubation period up to a certain level and subsequently reduced. A significant relationship was found between various organic residues and the incubation period in soil for N mineralization.

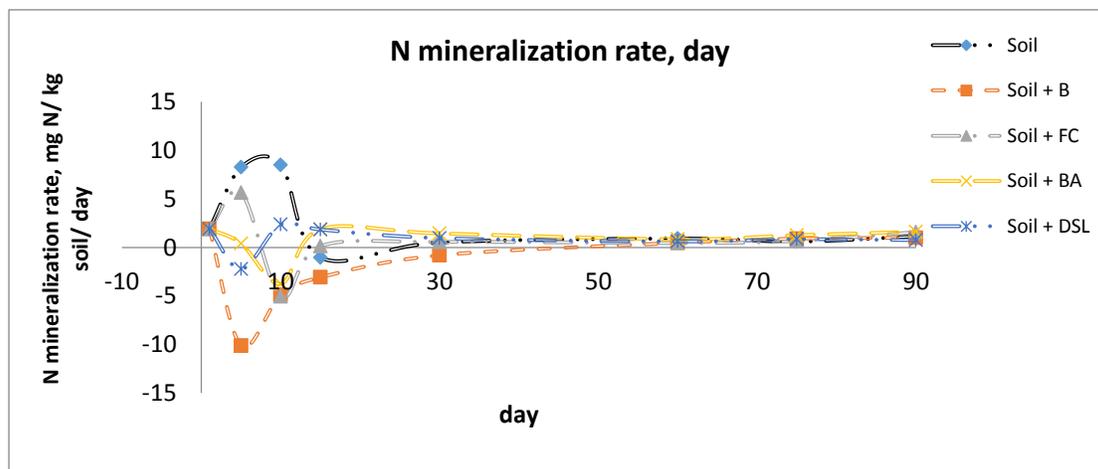
Fig. 4 shows the daily rate of NM for the treated and untreated soils during the incubation period. In general, the daily rate of NM increased on the 5<sup>th</sup> day from the beginning of incubation and then decreased throughout the incubation period with soil treated with B and DSL, while the rest of the treatments increased again on the 90<sup>th</sup> day of incubation. Daily N mineralization ranged between positive and negative, related to the type of residue treated with the soil and the incubation period. The maximum daily N mineralization reached 8.51 and 5.64 mg N kg<sup>-1</sup> soil day<sup>-1</sup> for the untreated soil on the 10<sup>th</sup> day of incubation and the soil treated with FC on the 5<sup>th</sup> day of incubation, respectively. On the first day of incubation, mineral nitrogen was constant at 1.92 mg N kg<sup>-1</sup> soil for all treatments, because the microorganisms had not yet been active. Moreover, the lowest available nitrogen level was -10.12 mg N kg<sup>-1</sup> soil day<sup>-1</sup> on the 5<sup>th</sup> day of incubation for

the soil treated with B. We conclude from this that adding B to the soil will suffer from a lack of nitrogen for a period of four weeks. Therefore, nitrogen-rich fertilizers must be added with it. On the 60th day of incubation, an increase in mineralized nitrogen appeared in all treatments. MDR of NM was low of amended soils with DSL and B due to their association with the high level of carbon mineralization as shown in Fig. 2. Because there are fewer microorganisms present at first, there is a higher level of available nitrogen; as the number of microorganisms rises, however, the level of available nitrogen decreases because it assimilated in their cells; and following death, the number of microorganisms rises once more as a result of the decomposition of the microorganisms themselves, which leads to a slight increase in the level of available nitrogen. According to research done by **Abbasi et al., (2015)**, available nitrogen increased as incubation time increased up to a certain point before decreasing.



\*A = Organic residues (bagasse, pressing mud, boiler ash and dry sugarcane leaves).  
 \*B = Incubation period (1, 5, 10, 15, 30, 60, 75 and 90 day).  
 \*AB = Interaction between organic residues and incubation periods

**Fig. 3: Nitrogen mineralization in untreated and treated soils with organic residues during the incubation period.**



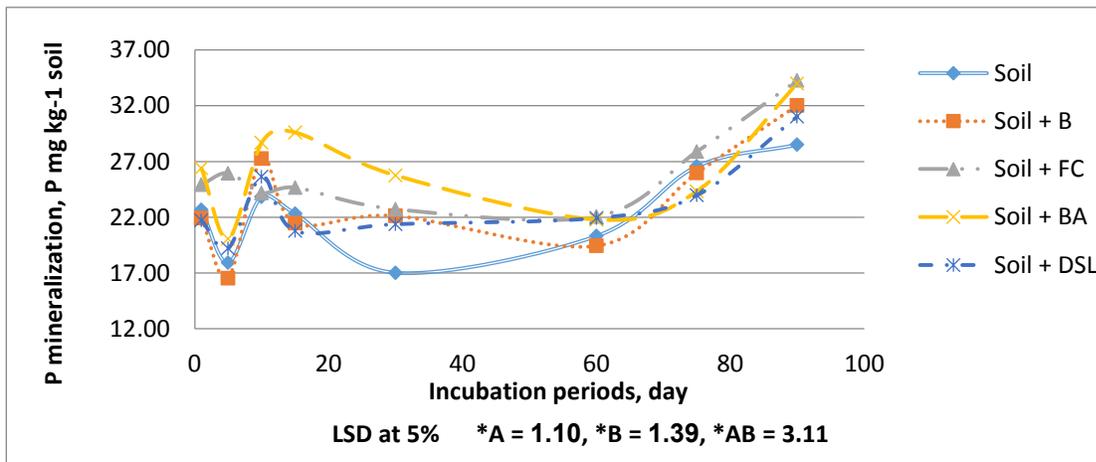
**Fig. 4. Daily nitrogen mineralization rate in soil untreated and treated with organic residues ( $\text{mg kg}^{-1}$ ).**

### b- Phosphorous mineralization

Fig. 5 illustrates the phosphorous mineralization (PM) throughout the incubation periods. The amount of P that was mineralized to its maximum level on the 90th day after incubation

period for treated soil with FC and BA was larger than the amounts of P that were mineralized at various intervals. Because initial phosphorus content of FC and BA were much higher compared to the other residues under study as shown in Table 2. On the other hand, on the 5th day of incubation, the available phosphorus content of the untreated soil (control), B, BA and DSL decreased due to the assimilation of available P in the organisms' body, but the FC-treated soil was increased. This trend may be due to the same reason as mentioned above (i.e. the initial high content of P in the starting material of the FC). While, on the 10<sup>th</sup> day of incubation, the MP was increased with all treatments under study. After the 10<sup>th</sup> to 60<sup>th</sup> days of incubation, MP decreased with all treatments under study because part of the phosphorus could be fixed or deposited in the soil as insoluble phosphorus. Available-P was reduced in soil treated and untreated with organic waste until 50–60 days of incubation, according to **Moharana et al. (2015) and Mishra et al. (2016)**. This may be because that P form is a fixed form (unavailable for microorganisms).

While after the 60<sup>th</sup> day of incubation, the PM increased significantly until the end of the incubation period (i.e., the 90<sup>th</sup> day) until it reached 34.26 mg kg<sup>-1</sup> of soil treated with FC. Then follow the maximum PM at the end of the incubation period was 33.99, 32.02, 31.02 and 28.50 mg kg<sup>-1</sup> for soil treated using BA, B, DSL and soil untreated (control), respectively. In general, PM increased with FC and BA-treated soil during all incubation periods, and this may be because they contained on higher concentrations of mineral elements, including phosphorus, compared to the rest of the treatments. In addition, BA was previously burned in sugar refineries, so the phosphorous in it is more mineral than organic.



\*A = Organic residues (bagasse, pressing mud, boiler ash and dry sugarcane leaves)

\*B = Incubation period (1, 5, 10, 15, 30, 60, 75 and 90 day).

\*AB = Interaction between organic residues and incubation periods

**Fig. 5. Phosphorous mineralization in untreated and treated soils with organic residues during the incubation period.**

Considering the information in Fig. 6, the maximum daily rate (MDR) of P mineralization from sugarcane residues B, FC, BA, and DSL in the soil was varied. At 75th day of incubation recorded the lowest daily rate of P mineralization (0.06 mg kg<sup>-1</sup> day<sup>-1</sup>) in soil treated with DSL. The MDR of P mineralization (5.08 mg kg<sup>-1</sup> day<sup>-1</sup>) with BA was obtained at the first day of incubation, followed by FC (3.60 mg kg<sup>-1</sup> day<sup>-1</sup>) because the initial content of available P for both BA and FC treatments was higher than for the rest of the residues organic used in this study. In general, the daily rate of mineralization of phosphorus for the treated and untreated soil was increased at the beginning of the incubation periods and then decreased with the increase in the

incubation periods. This may be because the activity and number of microorganisms increases at the beginning of the incubation periods and then decreases with the increase in the incubation periods, as shown in Fig. 6. It is believed that the decrease in the daily rate of mineralized P with the increase in the incubation periods may be due to two reasons. The first is that part of the mineralized P is assimilated in bodies of microorganisms, and the second is that the part of the available phosphorus is deposited in the soil. At the end of the incubation period (90 days), the mineralized P increased slightly, perhaps because part of the phosphorus was released from the bodies of microorganisms after their death in P available form. These results are consistent with Yu et al. (2013).

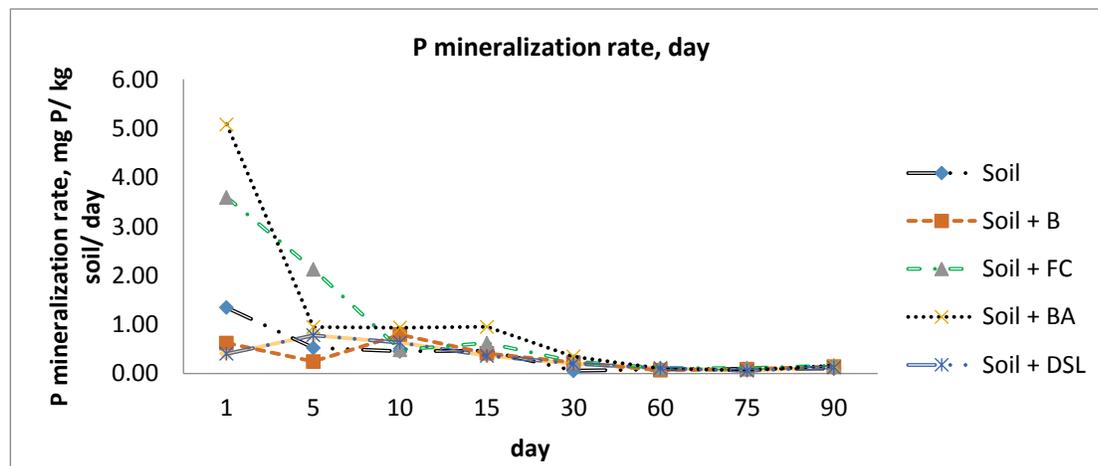
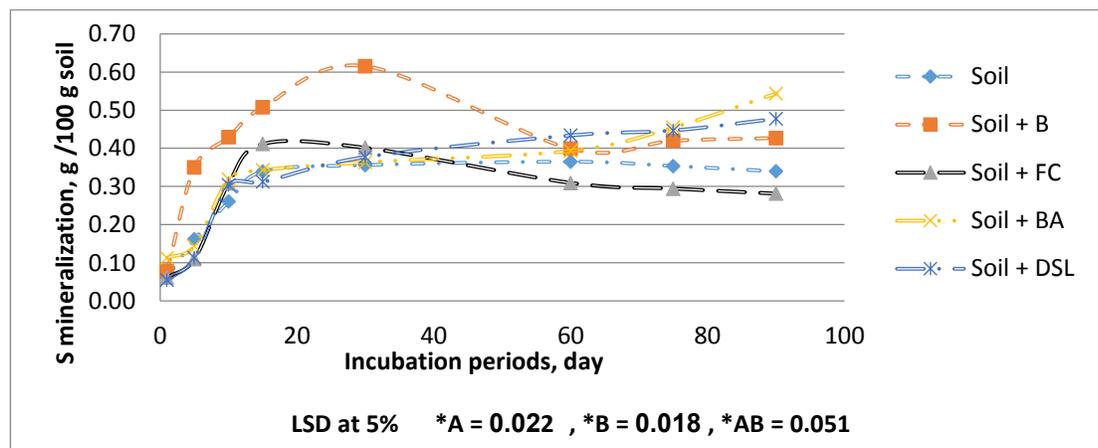


Fig.6. Daily phosphorous mineralization rate in soil untreated and treated with organic residues ( $\text{mg kg}^{-1}$ ).

### c- Sulfur mineralization

It is clear from Fig. 7 that, the mineralized sulfur values were in the form of  $\text{SO}_4$  were increased significantly in the first periods of the incubation, and then decreased with increasing incubation periods in soils treated with all organic wastes. As for the untreated soil (control), S mineralization increased continuously along the incubation periods, and this may be because the initial organic matter was in an advanced stage of decomposition. As for the S mineralization of the soil treated with BA, it followed the same trend as the untreated soil, perhaps because part of the sulfur in the boiler ash was in mineral form because it had been burned before. Regarding the soil treated with B was sulfur mineralization higher than other organic residues from starting incubation until 60th day from incubation. The maximum mineralization of S in soil treated with B was 0.62 % on the 30th day of the incubation period. Compared to all organic sugarcane wastes, the higher S mineralization from soil treated with B may be due to increased microbial activity for sulfur oxidation or because the initial sulfur content in the feedstock (sugarcane bagasse) was high compared to other organic wastes as in Table 2. The pattern of total S mineralization on the last day of incubation from different amendments was in the order  $B > BA > \text{Control} > \text{DSL} > \text{FC}$ . Regardless of the type of organic wastes, after 10 days of incubation, substantial increases above the baseline mineralization value of S were seen and until 30 days of incubation. Then it showed significantly declined trend at all the intervals up to 90 days of soil amended with B and FC. Additionally, Pareek et al. (2003) found that the mean S mineralization is lowest in FC and higher in C. According to Moharana et al. (2015), biochemical or biological mechanisms are usually responsible for the mineralization of S in soil. The biochemical process is characterized by the extracellular enzymatic hydrolysis that releases S from ester sulphates. There was a

considerable connection between the various organic wastes in the soil and the incubation period for the mineralization of S.



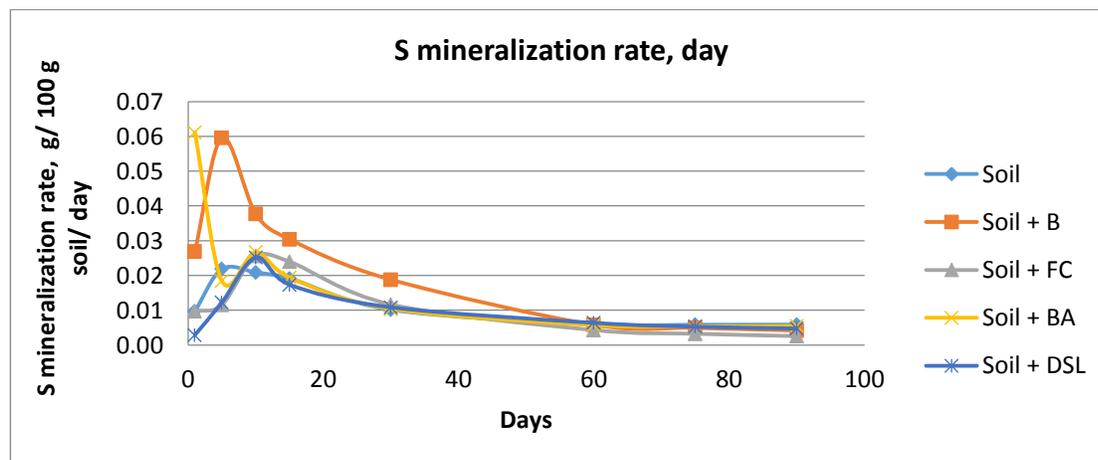
\*A = Organic residues (bagasse, pressing mud, boiler ash and dry sugarcane leaves).

\*B = Incubation period (1, 5, 10, 15, 30, 60, 75 and 90 day).

\*AB = Interaction between organic residues and incubation periods

**Fig. 7. Sulfur mineralization in untreated and treated soils with organic residues during the incubation period.**

Fig. 8 shows S mineralization daily rate in soil amended with organic sugarcane residue. From this, it is clear that, the daily S mineralization for all treatments under study took one direction, that is, an increase in mineralized S with the beginning of the incubation period until it reached the maximum mineralization of S between the 10<sup>th</sup> and 15<sup>th</sup> days of incubation, except for the soil treated B reached the maximum mineralization of S at 5<sup>th</sup> day of incubation, but for the soil amended with BA, a value of the mineralized S appeared on the first day of incubation 0.06 g / 100 g soil / day and then took the same trend as the other treatments.



**Fig. 8. Daily sulfur mineralization rate in soil untreated and treated with organic residues (g /100g soil).**

In general, the mineralization curve of S from organic residues in treated and untreated soil took the form of a normal curve during the first half of the incubation periods under study. The broad C: S ratio during the early stages of S mineralization may have immobilized S. However, microbial activity caused a resurgence of S mineralization after a certain amount of

time. Subsequently, microorganisms absorbed the nutrients, reducing microbial activity and population, which in turn decreased S mineralization.

#### 4-Conclusion

According to the study's key findings, the C, N, P and S mineralization increase during the incubation periods. 232.5 and 225.0 mg C kg<sup>-1</sup> soil were the maximum amount of C emitted at the end of the incubation period for soil treated with B and DSL, respectively. The maximum daily C mineralization was 10.7 mg kg<sup>-1</sup> for soil treated with B on the 5<sup>th</sup> day of incubation. While the highest amount of mineralized N at the end of the incubation period was 626.32 and 618.64 mg kg<sup>-1</sup> for soil treated with BA and FC, respectively. On the fifth day of incubation, the maximum daily N mineralization for the untreated soil was 70.04 mg kg<sup>-1</sup>. The soil treated with FC had the largest amount of mineralized P at the end of the incubation period was 34.26 mg kg<sup>-1</sup>. On the first day of incubation, the treated soil with BA had a maximum daily P mineralization of 5.08 mg kg<sup>-1</sup>. The maximum daily S mineralization appeared for soil treated with FC and B on the first and 5<sup>th</sup> days of the incubation period, respectively. These findings may clarify how soil releases C, N, P and S as well as explain how to turn organic wastes into compost. Sugarcane wastes are helpful in making compost and increasing soil fertility.

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