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Carbon and Nitrogen Mineralization Kinetics from Organically-Amended Upland Purplish Soil

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Abstract

The application of organic amendments in upland soils may influence soil carbon (C) and nitrogen (N) mineralization, which are very important for understanding plant nutrition. However, the kinetics of C and N mineralization from organically amended upland purplish soils has been poorly studied. Therefore, this study investigates C and N mineralization kinetics in organically amended upland purplish soils. Incubation experiments were conducted using soil samples collected from experimental plots that have been under long-term organic amendment fertilization, which includes: Organic manure (OM), crop residues (CR), combined organic manure with inorganic fertilizers (OMNPK), combined crop residue with inorganic fertilizers (CRNPK), conventional inorganic fertilizer (NPK), and no fertilizer (CK). The results showed that organically amended treatments increased C and N mineralization rates by 8 - 24% and 17 - 33%, respectively, compared with NPK. Likewise, the amount of potentially mineralizable carbon (Co) and nitrogen (No) increased by 4 - 9% and 15 - 20%, respectively, compared to the conventional NPK treatment. The rate constants for labile C (kC) and N (kN) were 6 - 29% and 3 - 27% higher than the NPK treatment, respectively. In addition, the initial potential rate of C (Co × kC) and N (No × kN) in organically amended soils were 10 - 37% and 18 - 52% higher compared to NPK. This study tried to show that the mechanisms of N supply was direct application of mineral N fertilizer and mineralization of organic N, while the N retention was reducing soil active N loss and storing more active N in cropland of purplish soil. These results suggest that the long-term application of organic amendments to upland soils may increase nutrient bioavailability.

Keywords

Agricultural Practices, First-Order Kinetics, Mineralization Rates, Organic Fertilizers, Soil Organic Matter

1. Introduction

Conventional agricultural practices have played a major role in sustaining the world's nutritional needs. Often characterized by mono-cropping, tillage and heavy reliance on inorganic fertilizers [1] [2]. However, the intensive nature of these conventional agricultural practices often results in soil degradation [3] [4], loss of nutrients and soil organic matter (SOM) depletion [5] [6]. Evidence suggests that heavy reliance of conventional agricultural practices on inorganic fertilizers has caused serious environmental pollution, especially C and N loss from agricultural soils into water bodies and has contributed to greenhouse gas emissions [1] [7].

To avert these problems, organic amendments are now being promoted as a means to reduce environmental pollution and soil degradation challenges associated with heavy loss of nutrients from inorganic fertilization [1] [8]. For example, some organic amendments such as pig manure and crop residues have been reported to contribute to SOM stability and slow turnover [9] and consequently increase crop productivity [10] [11]. Organic amendments increase crop productivity by supplying the crops nutrients soil, including organic carbon and nitrogen [12]. Nitrogen from organically amended soil is made available to plants through mineralization by the action of microorganisms under suitable environmental factors such as temperature and soil moisture [13]. Studies have shown that the mineralization of SOM is mainly mediated by soil microbial population, whose activities are dependent on the nature of the C and N present in the soil [14] [15]. It is, therefore, imperative to understand the C and N mineralization kinetics of agricultural purple soil to reduce nitrogen leaching potentials and increase soil carbon sequestration [16].

The purple soil covers an extensive area in the Sichuan Basin, an agrarian region in Southwest China. The soil is classified as Eutric Regosols as per FAO soil taxonomy and as Pup-Orthic Entisols according to Chinese soil taxonomy. The soil spans an area of 160,000 km^2 [17], accounting for 7% of total cropland area in China, and producing about 10% of the total crop output in China [18]. Moreover, long-term application of organic amendments can impact C and N mineralization kinetics, as well as their stabilization and retention in the soil. However, the impacts of long-term application of organic amendments on C and N mineralization kinetics in purple soil largely remain unknown. Therefore, this study aimed to determine the kinetic parameters of C and N mineralization in upland purple soils of the Sichuan basin region in Southwest China. We hypothesized that organically amended soils would have higher soil C and N mineralization kinetics parameters than inorganic fertilizer treatments.

2. Materials and Methods

2.1. Materials and Site Description

The study was conducted at the Yanting Agro-Ecological Station of Purple Soil (31˚16′N, 105˚28′E, and 420 m altitude Southwest China), which is a research station of the Chinese Ecosystem Research Network (CERN) in Sichuan province. The experimental site has a moderate subtropical monsoon climate, with an annual average air temperature of 17.3˚C and mean precipitation of 824 mm, with rainfall mainly occurring during the summer rainy season [19]. The soil is classified as Eutric Regosols in the FAO Soil Taxonomy and Pup-Orthic-Entisols in the Chinese Soil Taxonomy [20]. It has a clay loam texture, a pH (H_2O: Soil of 2.5:1 w/w) of 8.22, a bulk density of 1.330 kg m^{-3}, an organic C content of 8.75 g kg^{-1} and a total N of 0.62 g kg^{-1} [18]. The experimental plots were cropped conventionally with winter wheat (*Triticum aestivum* L.) from late October to May each year and then rotated with summer maize (*Zea mays* L.) from May through September. Organic fertilizers were applied with farmyard organic manure (fresh pig manure slurry) and wheat and maize residues (straw), while inorganic fertilizers were ammonium bicarbonate (NH_4HCO_3) supplied the required N, the calcium superphosphate ($Ca(H_2PO_4)2H_2O$) supplied the required P (90 kg P_2O_5 ha^{-1}) and potassium chloride (KCl) required K (36 kg K_2O ha^{-1}) were applied as basal fertilization for both wheat and maize. A yearly amount of N (280 kg N ha^{-1}), split into 130 kg N ha^{-1} in the wheat season and 150 kg N ha^{-1} in the maize growing season. A more comprehensive description of the site and field experiment could be found previously in [21]. Soil samples were obtained from experimental plots following a long-term application of organic amendments in field lysimeter plots (Size: 8 × 4 m^2) spanning between 2007 and 2022. The soil was used for incubation experiments.

2.2. Experiment Design Methods

The experiment was set up with plots and laid out in a randomized complete block design with six treatments and three replicates. The six treatments were: (1) No amendment (CK), (2) conventional mineral fertilizers (NPK) (3) organic manure (OM) composed of pig slurry (4) only crop residues at N equivalent to 20% of applied N in treatment of NPK (CR), (5) fresh pig slurry at N equivalent to 40% mineral N plus 60% mineral N at total N rate equivalent within NPK treatment (*i.e.*, OMNPK), and (6) crop residues at 20% equivalent plus 80% mineral N at total N same as in the NPK treatment (*i.e.*, CRNPK).

2.3. Soil Sampling and Preparation Methods

Three cores of field moist soil samples (0 - 20 cm) were collected from each treatments plots after maize harvesting using a flat-bladed stainless-steel shovel. In each replicated plot, three separate soil samples weighing 300 g and 100 g were taken from every three replicates and homogenized to make a composite sample of 100 g to complete four replicates for each treatment for incubation experiment. Field-moist soil samples were brought to the laboratory, air dried at room temperature for 48 hours, crushed and sieved through a 2 mm mesh to remove large plant materials and stone fragments. Soil samples were kept in plastic bags and stored in a refrigerator at 4˚C until the start of incubation experiments. Soil samples (30.0 g on an oven dried-basis) were placed into 250 mL glass jars for two parallels incubation samples, where the first part was used for CO_2 emissions measurement to monitor C mineralization, and the second part for N mineralization (NH_4^+-N and NO_3^--N) analysis. Glass jars bottles were air-tightened and incubated in the dark under controlled conditions (70% water holding capacity and 25 ± 1˚C) [2]. Before measuring C and N mineralization, samples were moistened to 70% water holding capacity and pre-incubated in the dark at room temperature (25˚C) for one week. Pre-incubation was required to minimize any possible effects of sampling time (during late summer), soil temperature and water content lost during field soil sampling and air-drying time [22] and for reducing labile organic matter concentration and activating soil microbial communities [2].

2.4. Soil C and N Mineralization Measurements Methods

After pre-incubation, the CO_2 released during the incubation period was used to measure the rate of C mineralization in the soil. Distilled water was added to each glass jars using a micropipette to 70% water holding capacity (7.0 g H_2O/40 g soil). The incubation experiments involved eight treatments with four replicates. Incubation glass jars were weighed weekly, so as to compensate for water losses in the treatments. At the time of the CO_2 gas sampling, the 250 mL glass jars, which were typically covered with plastic wrap, were sealed using an airtight butyl rubber stopper perforated by centered Perspex tubes and flushed with 100% pure dioxygen gas before closure. All glass jars were incubated at 25˚C. Four hours after closure, four samples of 20 ml of the headspace gas were sampled with airtight plastic syringes fitted with three-way stopcocks connected to the glass jars to measure CO_2 concentrations [23]. After sampling, the gas samples were immediately analyzed for CO_2 concentration using a gas chromatograph (Agilent GC-7890B, HP 5890II, Hewlett-Packard, Palo Alto, California, USA) equipped with a flame ionization detector (FID) for CO_2 detection. The CO_2 emissions (FCO_2) and C mineralization (F) and were calculated following Equations (1) - (2), respectively:

$$FCO_2 = \frac{\rho * V * \Delta C * 273}{m * \Delta t * (273 + T)} \tag{1}$$

$$F = \frac{\rho * V * \Delta C * 273}{m * \Delta t * (273 + T)} * \frac{12}{44} \tag{2}$$

where, F is the C mineralization (mg kg^{-1} h^{-1}); FCO_2 is the CO_2 emissions(mg C-CO_2 kg^{-1} h^{-1}); ρ is the CO_2 gas density (1.965 kg m^{-3}); V is the glass jars empty space volume (m^{-3}); ΔC is CO_2 concentration (ppm); m is oven-dried basis soil weight (kg); Δt is incubation time (h); and T is the incubation temperature(˚C).

Conversely, nitrogen mineralization was determined in a parallel soil incubation experiment, where the soil samples (5 ± 0.5 g) were extracted with 25 ml of 0.5 M K_2SO_4 solution and the supernatants were filtered through Whatman filter membranes (0.45 μm) for soil ammonium nitrogen (NH_4^+ -N), and nitrate-nitrogen (NO_3^- -N) measurements. Thereafter, soil NH_4^+ -N, and NO_3^- -N contents in the filtrate were analyzed using a continuous flow autoanalyzer (model AA3, Bran + Luebbe, Norderstedt, Germany). The total carbon mineralized (TCm) and total nitrogen mineralized (TNm) were calculated as the cumulative C and N mineralized during the 13-week incubation period.

2.5. Soil Analysis Methods

Soil samples were collected from different treatment plots and each soil sample (20.0 g) was fumigated with ethanol-free chloroform in a vacuum desiccator for 24 hours at room temperature in the dark. After complete fumigation, 5.0 ± 0.5 g of each soil sample was shaken (1 hr at 120 rpm) with 25 mL of 0.5 M K_2SO_4 solution and then filtered through a Whatman No. 5 filter paper. The filtrates were immediately refrigerated at −18˚C until analysis. At the analysis time, the filtrates were retrieved and left to deep freeze, after which the dissolved organic carbon (DOC), ammonia nitrogen (NH_4^+ -N) and nitrate nitrogen (NO_3^- -N) in each sample were determined using a continuous flow autoanalyzer (model AA3, Bran + Luebbe, Norderstedt, Germany).

2.6. Soil C and N Mineralization Kinetics Methods

From soil C and N mineralization data, first-order kinetic single exponential model was used to determine the potentially mineralized C and N and the mineralization rate (k) constants following the methods used in numerous previous experiments [2] [24] as described in Equation (3):

$$Ym = Yo\left(1 - e^{(-kt)}\right) \quad (3)$$

where, Ym (mg kg^{-1}) is the cumulative concentration of net C or N mineralized after time t; Yo (mg kg^{-1}) is the potentially mineralizable organic C or N pools at (t = o); t (weeks) is the time from the start of incubation experiment; k (week^{-1}) is the rate constant or potential turnover rate of soil labile C and N pools. The inverse of k value (1/k) was calculated and defined as the potential turnover time (week). To identify whether or how organic fertilization affects purplish soil organic C and N quality and availability, we calculated the initial potential rate of C or N mineralization (Yo × k, mg kg^{-1} week^{-1}) following the methods suggested by Campbell *et al.* [25] and Saviozzi *et al.* [26].

2.7. Statistical Analysis

Analysis of variance (ANOVA) was used for statistical analysis of the effects of the six treatments on C and N kinetics parameters in SPSS 16.0 (Chicago, IL, United States). The relationships between the total C mineralized and total organic carbon and total N mineralized and total nitrogen were verified by linear functional regressions. Data are reported in four replicates as mean standard error (±SE). Significant differences in the mean of estimated parameters among treatments were verified by the least significant difference test (LSD), at 95% confidence level ($P < 0.05$). The data graphics were drawn in Sigma plot software (version 12.5, Systat, Inc, USA).

3. Results

3.1. Soil C mineralization Kinetics under Organically-Amended Upland Purple Soil

To understand the carbon mineralization kinetics of upland purplish soil under organic and inorganic treatments, data from incubation experiment were fitted using a single exponential model (Figure 1) and carbon mineralization (Cm) kinetics parameters are shown in Table 1. The best fit for Cm using the single exponential model, where higher regression coefficients were found (R^2 = 0.968, OM), (R^2 = 0.980, CR), (R^2 = 0.972, NPK), (R^2 = 0.940, OMNPK) and (R^2= 0.946, CRNPK) (Figure 1) and standard error of estimate (SEE) ranging from 583.8 to 1264.6 (data not shown). At the end of 13 weeks, the total C mineralized (TCm) was significantly lower in NPK treatment (10,439 mg kg^{-1}), and TCm was significantly higher in CRNPK treatment with 13787 mg kg^{-1}. NPK was not significant with CR (11,291 mg kg^{-1}) ($P > 0.05$) (Table 1). Compared with NPK, TCm for organic amended treatments increased by 8 - 24% throughout the incubation period.

The Co concentration ranging from 15,050 to 17,213 mg kg^{-1} among all treatments with an increase by 4 - 13% in organic amended treatments compared to inorganic fertilizers (NPK) (Table 1). The Co and TCm showed a similar trend, but no significant difference was observed in Co between the treatments, whereas Co was greater than TCm in both organic amended and inorganic fertilizers treatments after 13 weeks of incubation as shown by Co/TCm ratios bigger than 1 (Table 1), indicating that some of the C fraction was still available for further microbial mineralization.

Organic amended treatments Co/TCm decrease by 3 - 15% compared with the NPK treatment (Table 1). The rate constant (kC) or decay rates for the labile C ranged from 0.0071 to 0.0099 $week^{-1}$ for the organic amended treatments and NPK treatment (Table 1). Significant differences were observed in kC between NPK and CRNPK treatments ($P < 0.05$). The organic amended treatments kC increased by 6 - 29% compared with NPK treatment. The estimated potential turnover time (1/kC) ranging from 101.0 to 161.3 for the for the organic amended treatments and NPK treatment, with significant differences between organic amended treatments and NPK treatment ($P < 0.05$). The organic amended treatments 1/kC decreased by 7 - 36% compared with the NPK (Table 1). The initial potential rate of C mineralization (Co × kC) ranging from 106 to 170 mg kg^{-1}, significantly varied between the organic amended treatments and NPK treatment.

The organic amended treatments Co × kC increase by 10 - 37% compared to the NPK treatment (Table 1). The results indicated the TCm, Co, Co × kC and Co/TCm increased while kC showed the most significant decrease in organic amended treatments over the entire 13 weeks period (Table 1).

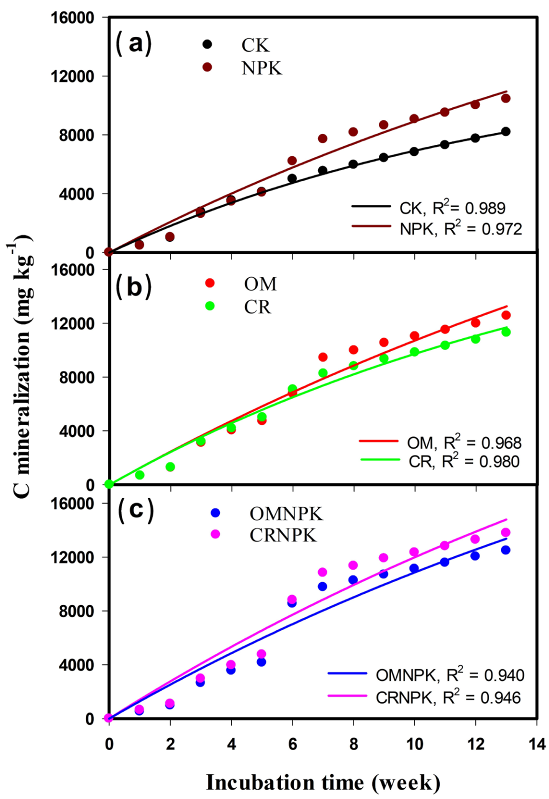

Figure 1. Carbon mineralization of organically-amended upland purplish soil during the incubation experimental period of 13 weeks at 25˚C. CK and NPK (a), OM and CR (b), and OMNPK and CRNPK (c). Each colored circle point indicates the mean for measured data of four replicates (n = 4). The line represents modeled single first order kinetics.

Table 1. Effects of organically-amended upland purplish soil on C and N mineralization kinetics parameters.

Treatments	C and N mineralization kinetics parameters						
	TCm (mg kg^{-1})	Co (mg kg^{-1})	k_C (week^{-1})	1/k_C (week)	Co × k_C (mg kg^{-1} week^{-1})	Co/TCm	TCm/TNm
CK	8183.86 ± 47.26d	12651.67 ± 276.77c	0.0062 ± 0.0001c	161.3 ± 1.66a	78 ± 2.13e	1.55 ± 0.03a	30.60 ± 0.96a
OM	12558.41 ± 206.46b	16528.33 ± 702.19ab	0.0085 ± 0.0003ab	117.6 ± 4.38cd	140 ± 3.20bc	1.32 ± 0.08ab	20.39 ± 0.61cd
CR	11291.06 ± 166.73c	15756.67 ± 750.07ab	0.0075 ± 0.0002bc	133.3 ± 3.88bc	118 ± 3.64cd	1.40 ± 0.08ab	19.87 ± 0.43d
NPK	10439.15 ± 266.63c	15050.00 ± 695.43b	0.0071 ± 0.0004bc	140.8 ± 6.84b	106 ± 6.35d	1.45 ± 0.08ab	25.15 ± 0.35b

Continued

OMNPK	12479.79 ± 264.60b	15705.00 ± 790.43ab	0.0095 ± 0.0005a	105.3 ± 5.46d	148 ± 2.96ab	1.26 ± 0.09b	25.05 ± 1.05b
CRNPK	13786.84 ± 580.68a	17213.33 ± 586.15a	0.0099 ± 0.0012a	101.0 ± 10.88d	170 ± 16.91a	1.26 ± 0.09b	22.63 ± 1.20bc

Mean ± SE: Means in columns followed by different lower cases letter are significantly different (LSD, $P < 0.05$) and means followed by the same lower cases letter are not significantly different (LSD, $P < 0.05$). TCm, total C mineralized; Co, potentially mineralizable C; k_C, rate constant for labile C; Co × k_C, initial potential rate of C; $1/k_C$, potential C pool turnover. No fertilizer (CK, control), Pig manure (OM), crop residues (CR), inorganic fertilizers (NPK), combined pig manure and inorganic fertilizers (OMNPK), and combined crop residues and inorganic fertilizers (CRNPK).

3.2. Soil N Mineralization Kinetics under Organically-Amended Upland Purple Soil

The N mineralization (Nm) data were fitted using a single exponential model (Figure 2) and the Nm kinetics parameters are shown in Table 2. The fitted exponential model for N mineralization under all the treatments showed high regression coefficients, which were $R^2 = 0.984$, (NPK), $R^2 = 0.981$, (OM), $R^2 = 0.986$, (CR), $R^2 = 0.983$, (OMNPK) and $R^2 = 0.984$, (CRNPK) (Figure 2) and low standard error of estimate (SEE) ranging from 24.1 to 31.7 (data not shown). The

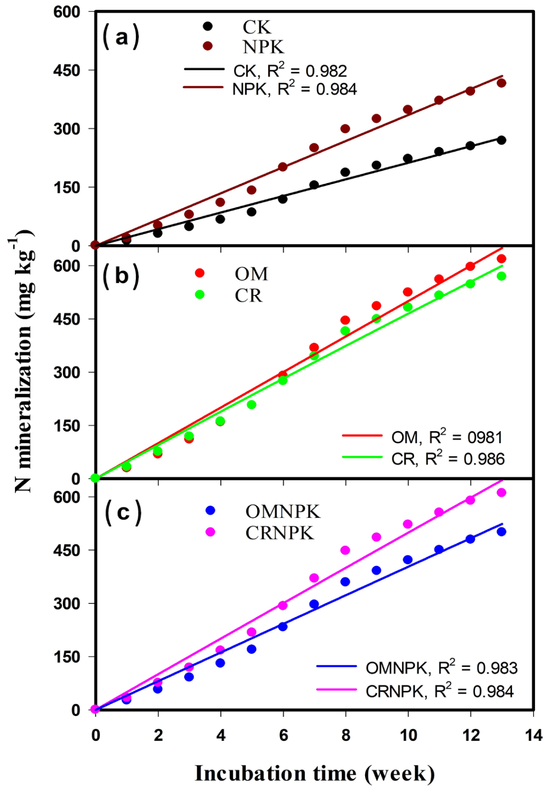

Figure 2. Nitrogen mineralization of organically-amended upland purplish soil during the incubation period of 13 weeks at 25˚C. CK and NPK (a), OM and CR (b), and OMNPK and CRNPK (c). Each colored circle point indicate the mean for measured data for four replicates (n = 4). The line represents modeled single first order kinetics.

total N mineralized (TNm) under all treatments are presented in Table 2. TNm values ranged from 415 to 618 mg kg^{-1}, with the OM and CRNPK treatments having TMn values significantly than the NPK treatment (Table 2).

The potentially mineralizable N (No) ranged from 753 mg kg^{-1} to 947 mg kg^{-1}, with the difference between organic and inorganic treatments (NPK) ($P < 0.05$) (Table 2). Although the No of organic amended treatments increase by 15 - 20% compared to NPK, significant differences were observed between the ratios of No/TNm, which ranged from 1.51 to 2.36 across all treatments ($P < 0.05$). Interestingly, the No/TNm ratio was greater than 1 (Table 2), showing that TNm released was lower than No for all treatments, which indicated that N fractions was still present for more microbial mineralization.

The rate constant (kN) for the labile N was 0.0033 to 0.0065 week^{-1} across the five treatments with significant difference between the treatments and higher kN was observed in the treatments OM, CR, and CRNPK treatments ($P < 0.05$). Moreover, the organic amended treatments kN increased by 3 - 27% compared to NPK treatment (Table 2). The estimated (1/kN) indicated the slow turnover times of the labile N mineralization, varying from 154 to 303 for all treatments.

Significant difference was observed between the treatments in 1/kN ($P < 0.05$), and the organic amended soil 1/kN decrease by 3 - 35% compared to NPK treatment. More interestingly, a significant difference was observed in the initial potential rate of N mineralization (No × kN), ranging from 3.60 to 6.10 mg kg^{-1} week^{-1}. The organic amended treatments (No × kN) increase by 18 - 52% compared to NPK (Table 2). Among all the treatments, TNm, kN, and No × kN were greater in the organic amended treatments than in the NPK treatment, whereas the No/TNm and 1/kN showed a contrast trend (Table 2). Furthermore, NPK treatment showed significantly higher TCm/TNm and Co/No ratios compared to the organic amended treatments. Consequently, the organic amended treatments TCm/TNm ratios decrease by 27% (Table 2) and the Co/No decreased by 10 - 14% compared with NPK (Table 2). Moreover, the total C mineralized (TCm) and soil total organic carbon were positively correlated ($P < 0.0001$) (Figure 3) across all the treatments at the end of the 13-week incubation period. A positive linear relationship was found between total N mineralized and soil total nitrogen (TN) ($P < 0.0001$) (Figure 3) across all treatments at the end of the incubation of 13 weeks.

Table 2. Effects of organically-amended upland purplish soil on C and N mineralization kinetics parameters.

Treatments	C and N mineralization kinetics parameters						
	TNm (mg kg^{-1})	N_O (mg kg^{-1})	k_N (week^{-1})	$1/k_N$	N_O x k_N (mg kg^{-1}week^{-1})	N/TNm	Co/No
CK	268.29 ± 9.60e	630.00 ± 16.71d	0.0033 ± 0.0002c	303 ± 13.70a	2.08 ± 0.06c	2.36 ± 0.13a	20.13 ± 0.70a
OM	617.61 ± 22.61a	931.67 ± 19.40ab	0.0065 ± 0.0005a	154 ± 9.70c	6.10 ± 0.56a	1.51 ± 0.03c	17.74 ± 0.67a

Continued

CR	568.78 ± 12.03b	881.67 ± 13.59b	0.0062 ± 0.0002a	161 ± 6.20c	5.45 ± 0.23a	1.55 ± 0.04c	17.90 ± 1.02a
NPK	415.02 ± 7.91d	753.33 ± 11.61c	0.0048 ± 0.0001b	208 ± 6.04b	3.60 ± 0.15b	1.82 ± 0.03b	20.02 ± 1.14a
OMNPK	499.64 ± 11.64c	890.00 ± 23.54ab	0.0049 ± 0.0002b	204 ± 7.19b	4.38 ± 0.22b	1.78 ± 0.05b	17.63 ± 0.66a
CRNPK	610.14 ± 6.30a	946.67 ± 23.66a	0.0062 ± 0.0001a	161 ± 2.98c	5.84 ± 0.25a	1.55 ± 0.02c	18.20 ± 0.56a

Mean ± SE: Means in columns followed by different lower cases letter are significantly different (LSD, $P < 0.05$) and means followed by the same lower cases letter are not significantly different (LSD, $P < 0.05$). TNm, total mineralizable organic N; No, potentially mineralizable N; k_N, constant for labile N; $1/k_N$, potential N pool turnover. No fertilizer (CK, control), Pig manure (OM), crop residues (CR), inorganic fertilizer (NPK), combined pig manure and inorganic fertilizers (OMNPK), and combined crop residues and inorganic fertilizers (CRNPK).

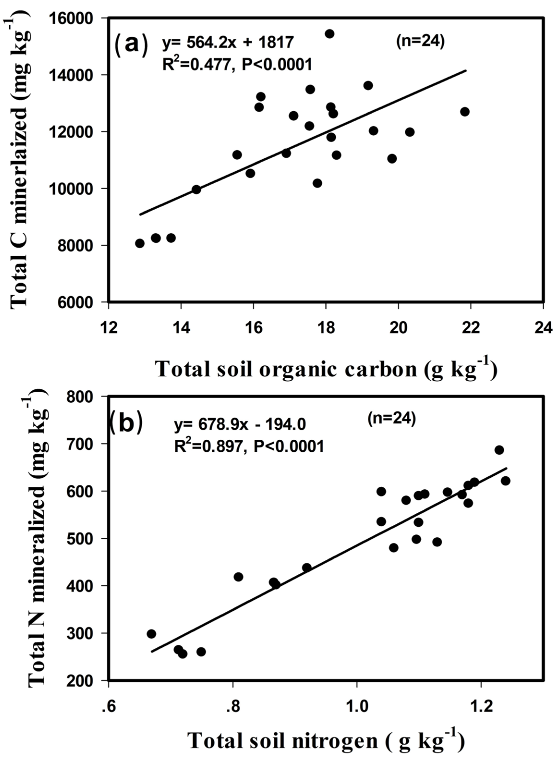

Figure 3. Relationships between total C mineralized (TCm) and soil total organic carbon (TOC) (a) and total N mineralized (TNm) and soil total nitrogen (TN) (b) of organically-amended upland purplish soil during the incubation period of 13 weeks at 25˚C, (n = 24).

4. Discussion

The results from Table 1 indicated that the incorporation of crop residue decreased the NH_4^+-N and NO_3^--N mineralization, showing there was an N immobilization due to the increase in microbial population that consume N as source of food for their cells growth [27]. The correlations between total N mineralized (TNm) and soil total nitrogen (TN) were positive, showing that the soil TNm increased linearly with increasing soil TN (**Figure 3**). Ros *et al.* [28] also observed similar results in predicting soil N mineralization. Both results indicated that certain soil conditions like SOM and soil N are the important factors controlling soil N mineralization [4]. Overall, our results showed that organic amendment practices could help in building soil organic carbon, which has the potential to increase soil N mineralization [9]. The results suggest that compared with NPK, organic amendments have a higher potential of building SOM and maintaining soil fertility over the long term.

The C and N mineralization kinetics parameters are used for determining the effects of agricultural management practices on soil C sequestration, soil nutrient turnover and fertility [2] [25] [29]. Campbell *et al.* [25] previously suggests using No concentration for characterizing the labile and readily mineralizable fraction of total N in the soil. In their study, Gregorich *et al.* [30] reported that No concentration can represent a measure of soil N availability to plants. The estimated Co was in the range of 12,652 to 17,213 mg kg^{-1}, which was higher than the values (653 to 1061 mg kg^{-1}) reported by Raiesi and Kabiri [2] from a calcareous loam soil. Additionally, the estimated No was in the range of 630 - 947 mg kg^{-1}, which was higher than the values (161 to 177 mg kg^{-1}) reported by [4] from soil with lower organic SOM. The results from **Tables 1-2** showed that Co and No were greater than the measured total C mineralized (TCm) and the total N mineralized (TNm), indicating the best fit of the single exponential model. Dou *et al.* [31] demonstrated that Co and No are the upper limits of soil C and N mineralization and might be higher than the measured TCm and TNm at the end of the incubation period. The results also indicate that there are still some soil organic C and N fractions left in the soil that can be available for more mineralization even after 13 weeks of incubation.

The present study showed the estimated kC of 0.0071 to 0.0099 $week^{-1}$ was higher than 0.000429 to 0.00510 reported by Rahman [13] for different manure and rice straw, but lower than 0.17 to 0.20 $week^{-1}$ reported by Raiesi and Kabiri [2] from loam calcareous soil. While the estimated kN 0.0033 to 0.0065 $week^{-1}$ is lower than 0.014 to 0.024 $week^{-1}$ reported by Raiesi and Kabiri [2] for calcareous loam soil. Previous studies have shown that the differences in C and N kinetics parameters of the different studies might be attributed to differences in soil properties, environmental factors, incubation temperature and period [2] [24]. Furthermore, the Co × kC and No × kN kinetics parameters could better indicate the SOM turnover than the other the kinetics parameters used alone, and for evaluating the effects of upland management practices on soil N dynamics as previously reported in other studies [25] [26]. Meanwhile, all the kinetics parameters showed clear changes in C and N mineralization from organic amended treatments and NPK treatment and are much lower in NPK treatment. Campbell *et al.* [25] demonstrated that No × kN could be more influenced by agricultural management practices than TN, No and kN. There were no significant differences in SOM between the organic amended treatments, but NPK had the lowest SOM because of the low C and N availability. Our results suggest that under different organic amendments and mineral fertilizers combinations, Co × kC and No × kN parameters can change in the available labile C and N pools of the organic amended upland purplish soil.

5. Conclusion

Soil C and N mineralization kinetics parameters of upland purple soil amended with organic and inorganic fertiliser treatments showed different trends at the end of the incubation experiment. The results showed that conventional NPK fertilized soils had lower soil C and N mineralization rates when compared to the organic amended treatments, with a lower turnover rate of soil organic matter. Other kinetics parameters: TCm, TNm, Co, No, kC, kN, Co × kC and No × kN from inorganic treatments were lower because of low available C and N. The results also show the potential benefit of the N release pattern of different organic amended treatments, which can replace inorganic fertilizers in upland purple soil. The contribution of this study was to underly that mechanisms of N supply was direct application of mineral N fertilizer and mineralization of organic N, while the N retention was reducing soil active N loss and storing more active N in cropland of purplish soil. Future studies should consider different soil depths and a wide range of quality and quantity of organic materials to fully understand C and N mineralization kinetics in slopy wheat-maize cropping systems.

Author Contributions

HB, and BZ conceptualized the study. HB and AC conducted soil sampling and performed the experiment. HB prepared the manuscript with contributions from the co-author.

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Conflicts of Interest

The authors declare no conflict of interest.

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