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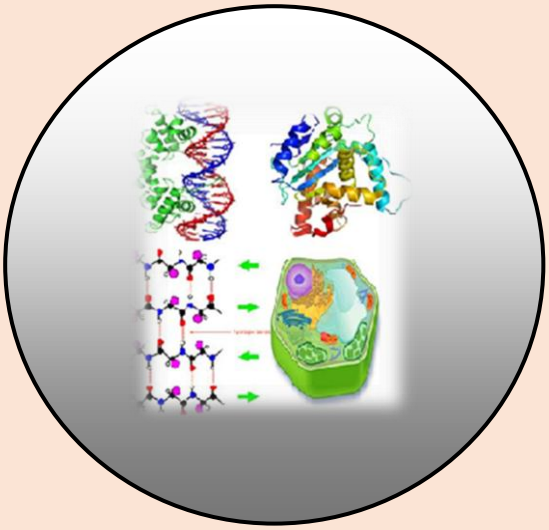

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RESEARCH PAPER

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Investigating the effects of Nitrogen, Phosphorus, Potassium and Sulfur Mineralization in the Soil

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ABSTRACT

The objective of this study was to explore the effect of long-term various fertilization on soil organic N mineralization potential (NMP). Nitrogen mineralization is the conversion of N from an organic form to an inorganic form as a result of microbial activity. Baseline N mineralization describes the conversion of N in soil organic matter to nitrate. Immobilization in soil science is the conversion of inorganic compounds to organic compounds by microorganisms or plants by which the compounds become inaccessible to plants. Ammonium-N is typically a short-lived intermediate in conversion of organic N to nitrate-N. Nitrogen mineralization is a complex process that involves a vast collection of microorganisms (bacteria, fungi, and actinomyces) acting on a wide array of substrates (crop residues, soil humus, dead microbial tissue, and manure) under varying soil environments (temperature, water content, and aeration) to produce a remarkably simple product (nitrate-N) that can be used by plants, lost to the atmosphere as N gases, immobilized, accumulated in soil, or leached from the soil-crop system. In this work the significant positive correlation between k with SMBC and SMBN (R2 = 0.93, p = 0.008 and R2 = 0.94, p = 0.006) suggested that the higher N and P mineralization rate might be contributed by the higher soil N and P microbial biomass in NPKM. The soil of fixed NH4 + and mineralized N were coupled. Long-term fertilizer application significantly improved the N mineralization rate in soil.

Keywords: Nitrogen mineralization, Soil, Phosphorus and Potassium.

INTRODUCTION

Globally, approximately 50% of the nitrogen (N) applied in agricultural fields is lost to the environment, which severely affects N use efficiency and deteriorates the environment. There is uncertainty in choosing the optimal fertilizer N rate due to the inherent variability in the soil N supply.

An accurate estimate of the soil's ability to supply N is essential for determining the optimum rate and time of fertilizer application required to develop sustainable land management strategies, optimize crop yield and quality, and minimize the adverse impacts of excessive N on the environment. Although most soils contain a large quantity of organic N, an appreciable portion of organic N is chemically or physically stabilized and resistant to microbial degradation, whereas a small portion is more labile and plays a prominent role as a source of substrate for N mineralization. Only when organic N is mineralized to inorganic N may it be easily taken up by plants. From the perspective of plant nutrition, soil organic N needs to be continuously activated to ensure the growth and development of plants. However, there is potential of leaching loss and N use efficiency reduction if soil mineral N is far beyond the absorption capacity of plants. Therefore, understanding the characteristics of soil N mineralization (Nmin) is of great significance for crop production and ecosystem health sustainability. The CERES-N model simulates N mineralization and immobilization from added organic matter in a relatively simple way (Godwin and Jones, 1991; Jones and Kiniry, 1986).

The model divides added organic material into three pools that differ in their decomposition rate constants.

Soil N mineralization is mediated by soil microorganisms. Soil microbial biomass N is a vigorous source of controlled N release during immobilization and re-mineralization. It was reported that soil N mineralization rate (NMR) was controlled by soil carbon (C) level, which acts as an energy source for soil microorganisms.

The addition of organic materials with low C and N ratio (C: N) is associated with N mineralization, and material addition with a high C: N ratio resulted in immobilization in a fine-loamy soil. Hence, an accurate assessment of N mineralization is essential for determining the nitrogen mineralization potential (NMP) and N application rate, measures of which are necessary to improve N use efficiency and minimize the risks of N losses and their impacts on the environment.

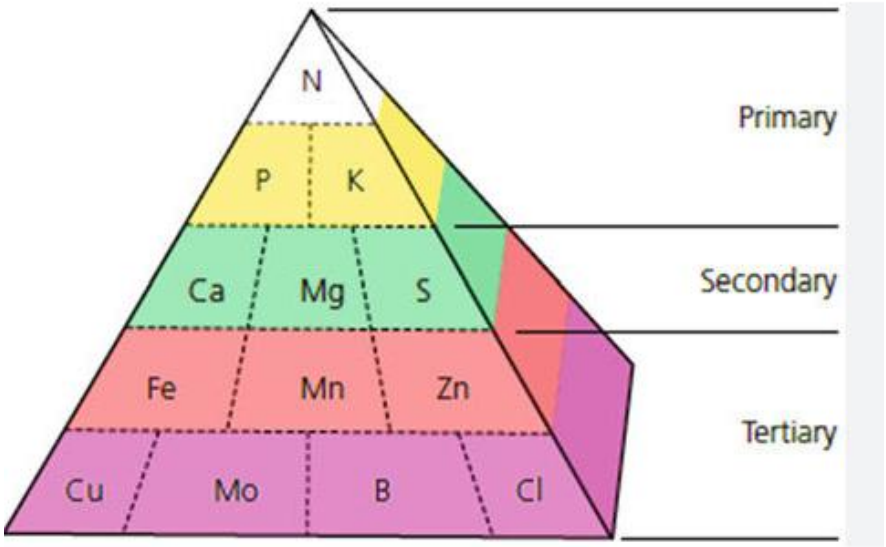


Figure 1. General essential plant nutrients (Adopted, Arnon and Stout 1939).

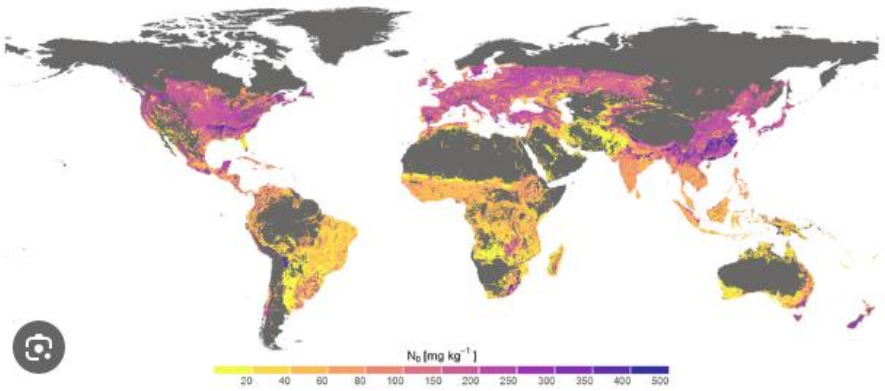


Figure 2. The global distribution of potentially mineralizable nitrogen (N 0..).

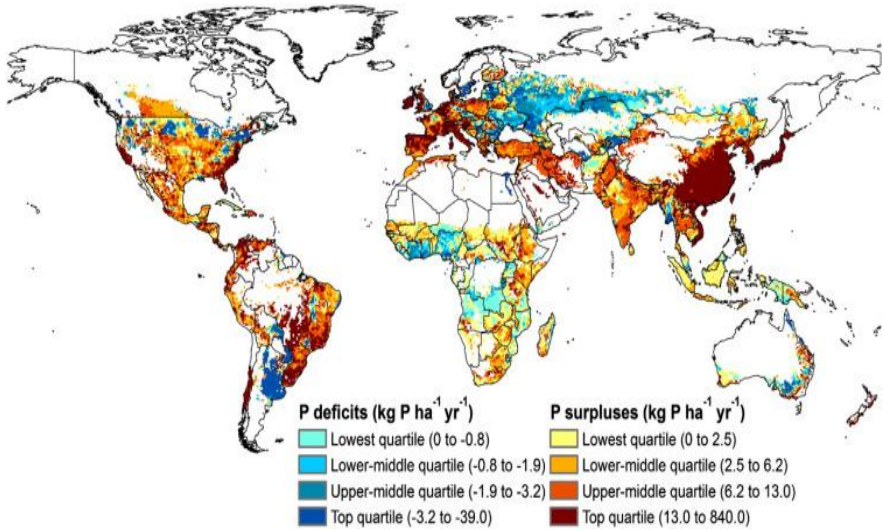


Figure 3. Distributions of P surpluses and deficits in world.

MATERIAL AND METHODS

Measuring Soil Microbial Biomass

Soil microbial biomass, the total mass of all organisms in soil, is commonly used to give an estimate of the response of soil microbiota to changing environmental conditions. Microbial biomass is most commonly measured using chloroform fumigation-extraction method in which microorganisms are first killed by exposing fresh soil to ethanol-free chloroform for a certain period of time (usually 24 h), extracting the C released from the lysed microbial cells with a salt solution, analysis of the net increase in soluble C multiplied by a conversion factor to determine microbial biomass C. Other common methods of microbial biomass determination include use of fatty acid profiles, substrate induced respiration (SIR) or biochemical indicators such as the measurement of ATP production (Jenkinson and Oades, 1979) or fungal ergosterol production Hedley, M.J.J.W.B. 1982. The amount of phosphate in soil microbial biomass was estimated by adding $CHCl_3$ to soil to lyse microbial cells and measuring the proportion of microbial-P released to 0.5 M $NaHCO_3$ extracts (pH 8.5). Calculations of total microbial-P were based on the difference between P removed by $NaHCO_3$ extraction of $ChCl_3$ treated and untreated samples.

This method was improved by (1) removing resin-extractable P from the soil before lysing microbial cells with $CHCl_3$, (2) measuring total P rather than inorganic-P in $NaHCO_3$ extracts, and (3) prolonging $NaHCO_3$ extraction from 30 min to 16 h. The efficiency of extraction of soil microbial-P was determined by measuring the P recovered from two species each of bacteria and fungi grown first in solutions having different P concentrations, then added to soil. The average proportion of microbial-P recovered from a neutral calcareous soil was 37% (K_P = 0.37). The K_p factor was confirmed by adding ^{33}P-labelled bacteria to a similar soil and measuring the added ^{33}P recovered (38%) by the $CHCl_3$-$NaHCO_3$ method.

The long-term experiment was established in 1990 located at the experimental station in Yuanyang (113°40′42″ E, 34°47′25″ N), Henan, China. At the station, the mean annual temperature (MAT) is 14.5 °C, the minimum annual temperature is −4.3 °C, the maximum temperature is 31.7–31.8 °C, and the mean annual precipitation (MAP) is 48.1 mm (Figure 1). The soil type is light-loam textured *Fluvo-aquic* soil (Aquic Ustochrept, U.S. classification). At the beginning of the field study in 1990, treatment samples across the field were collected in each plot and analyzed. This field had an average of soil organic C (SOC) content of 5.86 g kg^{-1}, a total N (TN) content of 0.65 g kg^{-1}, a total phosphorus (P) content of 0.64 g kg^{-1}, a total potassium (K) content of 16.9 g kg^{-1}, an alkali-hydrolysable N content of 76.6 mg kg^{-1}, an Olsen-P content of 6.5 mg kg^{-1}, an ammonium-acetate extracted K content of 74 mg kg^{-1}, and a pH of 8.3 at the start of the experiment. The crop rotation cycle was winter wheat followed by summer maize each year. Maize is sown in June and harvested in mid-September and winter wheat is planted in early October and harvested in early June the following.

Nitrogen Mineralization Incubation

Mineralizable N pools were quantified using a 30-week long-term aerobic incubation procedure, as described to obtain the potentially mineralizable soil N (N_0). Briefly, 15 g of each treatment sample and 15 g of sand quartz were moistened and mixed, transferred into a leaching tube, and wetted to 55% of the soil's water-holding capacity. Mineral N initially present was removed by leaching with 0.01 mol L^{-1} $CaCl_2$, which was followed by the addition of a zero-N nutrient solution, suction (≈80 kPa) and incubation at 35 °C. After 2 weeks, mineral N was recovered by leaching with 0.01 mol L^{-1} $CaCl_2$, followed by a zero N nutrient solution, suction, and incubation. The leachates were analyzed for NH_4^+-N and NO_3^--N concentrations using a continuous flow analyzer (Foss FIASTAR 5000 Analyzer). Afterwards, the treatments samples were analyzed for the contents of total N, SOC, and fixed NH_4^+. All treatments were tested with 4 replications. Whether net N immobilization took place in the incubation of this manure cannot be said because the first measurement was done after 30 d in the study by Palomino et al. (2019).

Calculation of NMP and NMR Constant

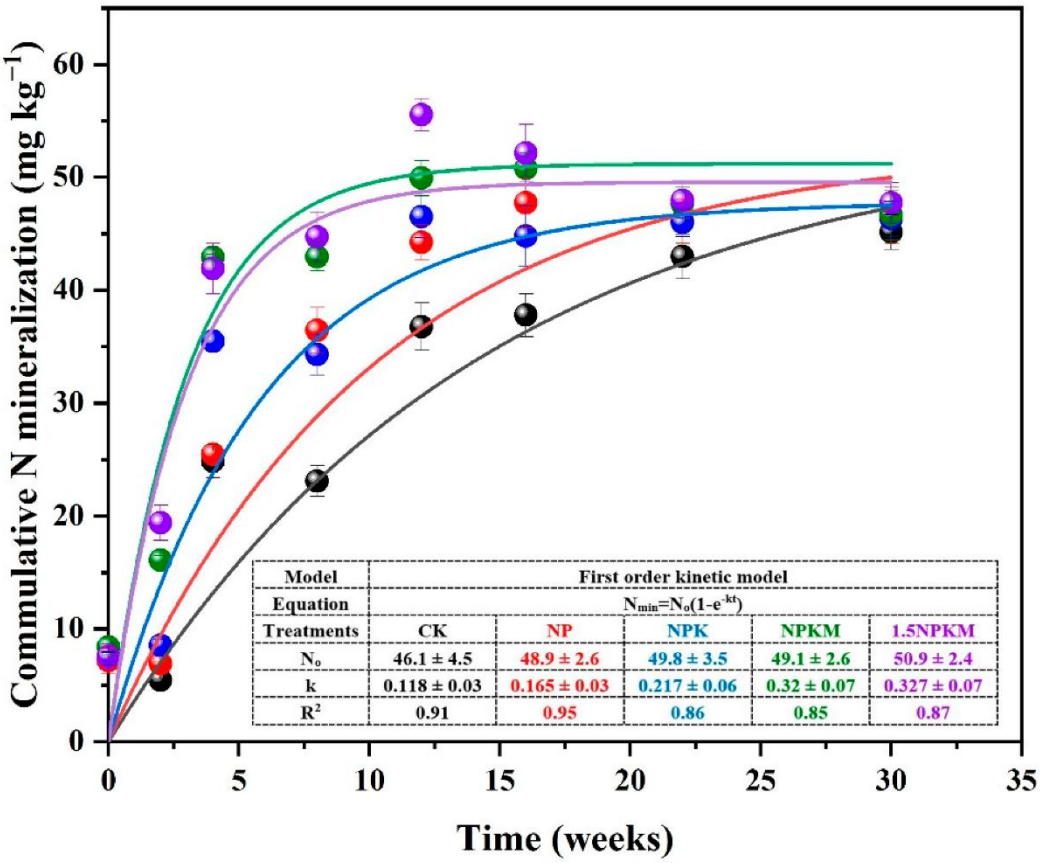
The cumulative N mineralization defined as "the average of the N mineralization rates in all different periods" was calculated over the sum of 30 weeks of incubation. Three different pools of mineralizable N were calculated as described in. The NMP and rate of mineralized N were calculated using the first-order, nonlinear kinetic model using the Marquardt iteration method as follows:

$Nmin=N0\ (1-e^{-kt})$

Where N_{min} is the cumulative N mineralized (NH_4^+-N + NO_3^--N) at time *t* (Pool II), N_0 is the NMP (mg N kg^{-1}), and *k* is the NMR.

RESULT AND DISCUSSION

I concluded that soil bacteria responsible solubilization and mineralization P: *Pseudomonas spp., Agrobacterium spp.,* and *Bacillus circulans* of *Azotobacter, Bacillus Burkholderia, Enterobacter, Erwinia, Kushneria, Paenibacillus, Ralstonia, Rhizobium, Rhodococcus, Serratia, Bradyrhizobium, Salmonella, Sinomonas* and *Thiobacillus*. The essential microbial fungi is *Achrothcium, Mortierella, Myrothecium, Oidiodendron, Paecilomyces, Penicillium, Phoma, Pichia fermentans, Populospora, Pythium, Rhizoctonia, Rhizopus, Saccharomyces, Schizosaccharomyces, Schwanniomyces, Sclerotium, Torula, Trichoderma* and *Yarrowia.*



Model	First order kinetic model				
Equation	$N_{min}=N_o(1-e^{-kt})$				
Treatments	CK	NP	NPK	NPKM	1.5NPKM
N_o	46.1 ± 4.5	48.9 ± 2.6	49.8 ± 3.5	49.1 ± 2.6	50.9 ± 2.4
k	0.118 ± 0.03	0.165 ± 0.03	0.217 ± 0.06	0.32 ± 0.07	0.327 ± 0.07
R^2	0.91	0.95	0.86	0.85	0.87

Figure 4. Cumulative mineralized N, N mineralization potential (N_0), and constant rate (*k*) differences among treatments with long-term fertilization treatments in relation to time. The N_0 and *k* were obtained according to equation ($N_{min} = N_0\ (1 - e^{-kt})$. chemical nitrogen and phosphorus fertilizer (NP), NP with K fertilizer, NPK with manure application, 1.5 rates of NPKM.

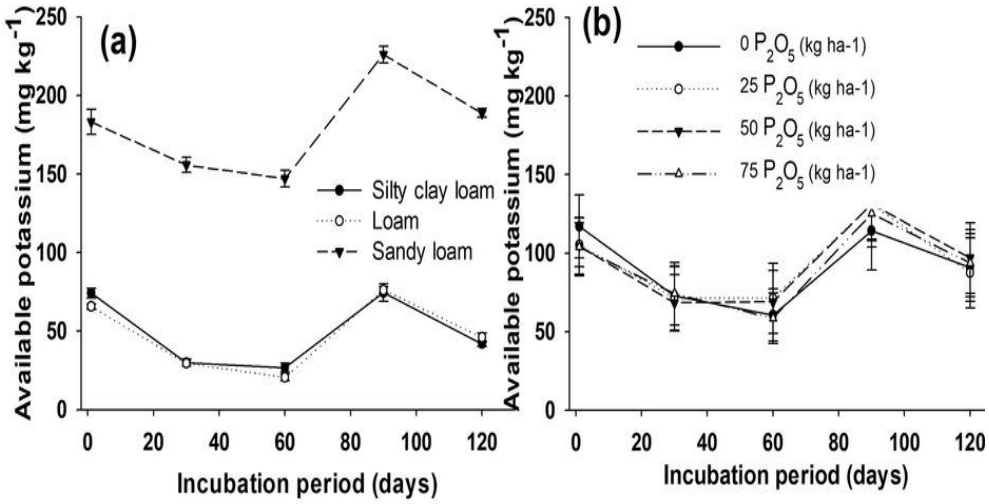


Figure 5. Potassium mineralization after 120 days of incubation.

The Relationship between NMR and Soil Microbial Biomass

A significant correlation was identified between the mineralized N rate and soil microbial biomass (SMBC: $R^2 = 0.93$, $p = 0.008$; SMBN: $R^2 = 0.94$, $p = 0.006$). Likewise, the SOC and TN ratio (C: N) was significantly higher in the CK treatment than the 15.NPKM treatment during the 30 weeks. The C: N increased with time during the first 2–12 weeks and then decreased during weeks 12–30. Fig 5 shows schematic representation of the organic acids that may be produced by PSM and used to solubilize inorganic forms of phosphate.

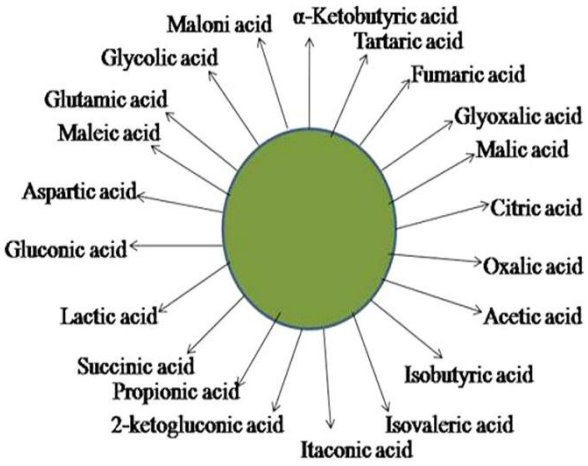


Figure 6. Shows schematic representation of the organic acids.

CONCLUSIONS

Soil microbial biomass (bacteria, fungi and protozoa) is a measure of the mass of the living component of soil organic matter. The microbial biomass decomposes plant and animal residues and soil organic matter to release carbon dioxide and plant available nutrients. The activity of the microbial biomass also has a direct impact on soil structure. As bacteria grow they produce polysaccharide gels, which help stick soil aggregates together. Fungi also helps stabilize soil aggregates as the long branching structures they produce, called filamentous hyphae, help entangle soil particles and bind them together.

Organic fertilizers and composts are valuable sources of nutrients that are extensively used in organic agriculture as well as in conventional systems. Their repeated application can increase soil fertility and soil organic matter (SOM) content (Lazicki, et al., 2020), which in turn helps maintain or improve soil health. The positive effect on soil health has resulted in increased interest in the use of organic amendments, especially compost, beyond organic agriculture (Norris and Congreves, 2018).

Identifying and including these properties (e.g., uric acid in the case of poultry manure) in future models may lead to an improved accuracy of predictions. The variability observed within certain groups of organic amendments indicates where further research can help to improve N mineralization models. However, the information available for individual batches of commercial amendments is generally limited, making net N mineralization and immobilization predictions based on the C/N ratio often the best option available.

Nitrogen mineralization is a complex process that involves a vast collection of microorganisms (bacteria, fungi, and actinomyces) acting on a wide array of substrates (crop residues, soil humus, dead microbial tissue, and manure) under varying soil environments (temperature, water content, and aeration).

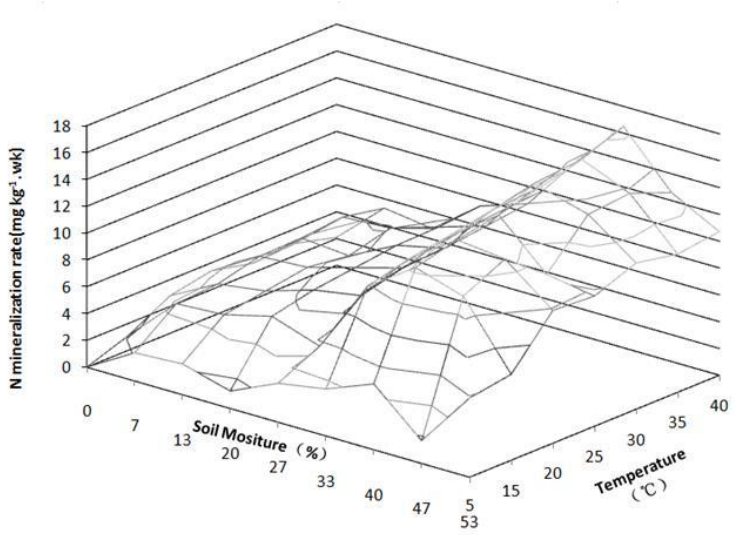


Figure 7. Shoe effect of water and temperature on N mineralization.

The improved water effect equation can be used to describe effect of water content on soil N mineralization with regard to the interaction of moisture and temperature. The effect of soil water content on soil N mineralization rate was non-linear. When the soil moisture content was less than 40%, the N mineralization rate increased with increasing soil moisture content, while upon exceeding 40%, the soil N mineralization rate decreased. The effect of temperature on the soil N mineralization rate was basically consistent with the variable temperature culture experiment.

Long-Term Fertilization

We investigated the dynamics of soil organic C and total N concentrations during the 30 weeks of incubation to determine whether N mineralization was accompanied by C mineralization. As expected, C: N increased during the first 2 weeks and decreased at 16–30 weeks.

Moreover, this ratio was consistently higher in CK than in 1.5 NPKM; however, the C: N in 1.5 NPKM was more consistent over time than that in CK. It suggested that N mineralization is not always synchronized with C mineralization and that the relative mineralization rate of N to C is higher in high-fertility treatments. The latter finding is a typical one, as the degradation of soil organic matter and the mineralization of C and N are mediated primarily by soil microorganisms.

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