**Effect of Crop Rotation and Continuous Cropping on Nitrogen Mineralization Characteristics in Yellow Cornfield**

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**Abstract**

In order to find out the characteristics of soil nitrogen (N) mineralization in corn field under rotation and continuous cropping in yellow soil area, Soil N mineralization and cultivation were studied by in situ culture method. Three treatments were established to study the effects of crop rotation and continuous cropping on soil N mineralization change characteristics during corn growth season, which are non-fertilization + tobacco-corn rotation (CK), conventional fertilization + tobacco-corn rotation (CR) and conventional fertilization + continuous cropping of corn (CC). The results showed that the early growth of maize (May 20) showed N fixation, while the late growth (July 15) showed N mineralization. The highest values of soil net ammonification rate, net nitrification rate and net N mineralization rate of all treated maize fields appeared in the later stage of crop growth, ranging from 0.12–0.15, 0.69–0.83 and 0.83–0.98 mg kg⁻¹ d⁻¹. During the whole growing period of maize, the rate of net ammonification was the highest in rotation. In the middle stage of maize growth, the net nitrification rate and net mineralization rates of rotation were higher than those of continuous cropping. In the later period of corn growth, the net nitrification rate and net mineralization rates of continuous cropping were higher than those of rotation. In rotation, the promotion rates of nitrification and N mineralization in soil were 3.04 and 6.08 times higher than those in rotation respectively. What’s more, the rotation could contribute to the N mineralization earlier appearance in corn field. Correlation analysis showed that the rate of net N mineralization under treatment of conventional fertilization + rotation cropping was related to soil nitrate content (P <0.05), and the net N mineralization rate under treatment of continuous cropping was unaffected by the local soil moisture content. As a result, crop rotation plus conventional fertilization is conducive to improve and promote soil N mineralization in yellow corn field. Therefore, reasonable rotation is an important way to improve N mineralization in yellow soil corn field. © 2018 Friends Science Publishers

**Keywords:** Maize field; N mineralization; Crop rotation; Continuous cropping

**Introduction**

Nitrogen (N) is of great importance in agricultural production and is one of the most important nutrient limitation factors. Soil supplied at least 50% of the N for crops absorption (Orino, 1992), whereas inorganic N pools (nitrate and ammonium) in the soil account for less than 2% of the total N in the soil (Melillo, 1981). Crops obtain mineral N mainly through soil N mineralization, which is also the essence of soil N supply. In mineralization, N conversion contains two important processes: nitrification and ammonification, of which conversion rate is a key factor in determining potential N losses (Aulakh and Singh, 1997). Therefore, focusing on the characteristics of soil N mineralization is of great significance for the sustainable development of agriculture.

Yellow soil is one of the main cultivated soils in southwest China. Among them, most of the food crops are mainly corn. There are some reports on the characteristics of continuous cropping and rotation system on the mineralization of maize field nitrogen. According to research reports, studied the soil N mineralization of wheat-corn rotation by applying N fertilizer and pointed out that the N mineralization rate and the nitrification rate of soil without fertilization were all lower than those of different fertilization treatments(Liu et al., 2016a), studied the carbon and N mineralization of soybean and maize root zone by continuous cropping and rotation; and they suggested that the amount of N mineralization for continuous cropping of soybean and corn were higher (Yan, 2013). There are many factors that influence soil N mineralization, and many studies showed that soil moisture content is of great significance to soil N mineralization (Zhu et al., 2013; Hu et al., 2014; Liu et al., 2015).

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However, few reports have been reported on the characteristics of soil N mineralization under continuous cropping and rotation. Under the long-term experimental conditions, the net N mineralization research on the relationship among net mineralization rate and promotion rate of N as well as soil moisture has not been reported yet. Therefore, in this paper we studied the effects of continuous cropping and crop rotation on the relationship between soil N mineralization and soil moisture in the yellow soil region of southwestern China under long-term experimental conditions in order to clarify the impact of different cropping systems on soil N mineralization and provide a scientific basis for sustainable development.

Materials and Methods

Overview of Test Area

The experiment was conducted in Longgang Long-term Nutrient Research Station in Guizhou Province in April to September of 2016, featuring geological location at E107°06′40.8″, N26°52′24.8″, elevation of 1,130 meters, frost-free period for 240–265 days, annual average temperature of 13.5°C to 14.6°C, annual sunshine duration for 948.2–1,084.8 h and average rainfall of 1,129.9–1,205.9 mm. The test area was established at the corn and maize wheel as locating points for experiment since 2008. The test area was established at the corn and maize wheel as locating points for experiment. Crop rotation was one year of planting corn and another year for tobacco (Crop rotation is a rotation between corn and tobacco). Continuous cropping was the annual corn crop. In addition, Shundan No. 7 corn variety was selected for experiment in yellow soils with fertility status from 0 to 20 cm featuring total N 1.6 g.kg⁻¹, total phosphorus 0.6 g.kg⁻¹, organic matter 39.7 g.kg⁻¹, alkali-hydrolysable N 136.0 mg.kg⁻¹, available phosphorus 12.2 mg.kg⁻¹, rapidly-available potassium 153.1 mg.kg⁻¹ and pH7.4.

Test Design and Management

The experiment was designed with three treatment processes: No fertilizer + Crop rotation (CK); inorganic fertilizer + Crop rotation (CR); inorganic fertilizer + Continuous cropping (CC) with specific fertilizer rate (Table 1). The basic fertilizer used during corn experiment was composed of compound fertilizer 75 kg.hm⁻² (N: 32%, P₂O₅ 4%), calcium superphosphate 407 kg.hm⁻² (P₂O₅ 14%) and potassium sulfate 118 kg.hm⁻² (K₂O 51%). In addition, phosphate and potash fertilizers were applied in the basic fertilizer at one time. After application, the ammonium nitrate 103 kg.hm⁻² (N: 35%) was used for the first additional fertilization and ammonium nitrate 171 kg.hm⁻² (N: 35%) for the second additional fertilization.

First, a 10 cm wide field ditch was dug out in the cornfield, and applied basic fertilizer on one side of the ditch and transplanted the corn seedlings on another side; the plants were earthen up and finally applied additional fertilizer on the soil surface 5 cm away from maize plants for two times. Other management measures were implemented in accordance with the management and cultivation system of local cornfields. Moreover, the corn seedlings were applied with basic fertilizer and transplanted on May 8th based on the planting distance of 33 cm, row spacing of 60 cm and cultivated density of 50001 plants per hm². There were 90 plants in each row and 8 rows in each community (total 720 plants). The first additional fertilizer was applied on June 1st, and second additional fertilized on June 24th.

Sample Collection

Field samples were collected from May to August in 2016 and in situ culture method was used. Three plugged mineralized tubes (4 cm in diameter and 25 cm in length) were installed in each treatment area for repeat test three times. The bottom of the mineralized tube was covered with mesh bags and the tubes were then buried in the depth of 20 cm between the plantation plow. The placing conditions among all treatments must be consistent, and the test were not set in the protection line. Before transplanting corn, two intermediate soil samples (0–20 cm soil layer) were taken and impurities were removed. After passing through a 5 mm sieve, the soil were divided into two parts with quartering: one sample in sealed pouch and being placed in an ice tray to store at low temperature, which will be taken back to the laboratory for determination of soil moisture and mineral N (nitrate- and ammonium-N); another part of the soil were put into the mineralized tube and buried in 0–20 cm of soil where sample had been collected. The soil sample in the mineralized tube was stored in a sealed bag after being cultured for 2 weeks and stored in the ice box at low temperature. The sample was taken back to the laboratory to determine the soil water content and mineral N (nitrate- and ammonium-N). The incubation period and sampling period were for two weeks. Each time collecting the soil sample from mineralization tube, the next round of cultivation was carried out simultaneously until the end of crop harvesting. Meteorological data were recorded automatically by OnsetHOBO temperature and humidity data logger (Fig. 1).

Sample Test

The content of NH₄⁺-N and NO₃⁻-N were measured by a continuous flow analyzer (Flastar 5000 Analyzer) (Bao, 2000).

Calculation and Data Analysis

\[
\text{Net N mineralization rate of soil} = \frac{\text{amount of mineralized N after cultivation} - \text{amount of mineralized N before cultivation}}{\text{days of cultivation}}
\]

\[
\text{Net nitrification rate of soil} = \frac{\text{amount of nitrate N after cultivation} - \text{amount of nitrate N before cultivation}}{\text{days of cultivation}}
\]
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Net ammonification rate of soil
\[ \text{amount of mineralized ammonium N after cultivation} - \text{ammonium N before cultivation} \]
\[ \text{days of cultivation} \]

Promotion rate of soil N mineralization (%)
\[ \frac{(N \text{ mineralization during cultivation after adding of N} - N \text{ mineralization during cultivation without adding of N})}{N \text{ mineralization during cultivation without adding of N}} \times 100 \]

Promotion rate of soil nitrate N (%)
\[ \frac{(\text{amount of nitrate N during cultivation after adding of N} - \text{amount of nitrate N after cultivation without adding of N})}{\text{amount of nitrate N after cultivation without adding of N}} \times 100 \]

The test data can be arranged into a diagram via EXCEL 2010 and analyzed with SPSS 11.5 software. Moreover, the significance test shall be analyzed with Duncan method.

Results

Effect of Continuous Cropping and Crop Rotation on Net N Mineralization Rate

Continuous cropping and rotation of corn fields showed a more consistent net N mineralization rate variation (Table 2). Early growth (May 20) of maize showed N fixation, while late growth (July 15) showed N mineralization. In the early stage of maize growth (May 20), the net ammonification rate of soil was zero and no ammonium formation occurred (Table 2a). At the same time, net nitrification and net N mineralization rates were negative and mainly showed net retention (Table 2b, c). As the corn growing (June 17), net ammonification rate was negative, showing net retention; while the net nitrification rate and net N mineralization rate were positive, showing net N mineralization. In the later growth stage of maize (July 15), the net ammonification rate, net nitrification rate and net rate N mineralization of soil were positive, ranging from 0.12–0.15, 0.69–0.83 and 0.83–0.98 mg kg\(^{-1}\) d\(^{-1}\), showing net mineralization. They were the highest among maize growing season, indicating the highest rate of N mineralization in later maize growth stage.

From the comparison of the treatments of the whole corn growing season, the net nitrification rate and the net N mineralization rate in the early stage of maize growth (May 20) ranged from -0.42 to -0.03 mg kg\(^{-1}\) d\(^{-1}\), the order was: CC>CK>CR, and there was a significant difference among treatments (P<0.05). In the middle stage of maize growth (June 17), the soil net ammonification rate, net nitrification rate and net N mineralization rate of CR were higher than those of CC. Net ammonification rate of CC was lower than those in treatments of CC and CK in the late growth stage (July 15). Among them, CC treatment and CR treatment showed significant difference (P<0.05). However, the net nitrification rate and net N mineralization rate were higher in CC treatment than CK treatment and CR treatment, and CC treatment and CR treatment were significantly different (P<0.05). The results showed that continuous cropping and crop rotation had different effects on N mineralization in corn field. Among them, rotation of corn field was beneficial to increase the rate of net soil ammonification, while continuous cropping of corn field was beneficial to increase soil net nitrification rate and net N mineralization rate.

Effects of Continuous Cropping and Crop Rotation on the Rate of N Mineralization

The trend of nitrification promoting rate in corn field was consistent with that of N mineralization promoting rate, while continuous cropping and crop rotation showed opposite influence on the rate of nitrification and N mineralization in corn field (Table 3). In the early stage of maize growth (May 20), the promoting rates of soil nitrification and N mineralization were -81.62 mg kg\(^{-1}\) d\(^{-1}\) (both showed inhibition) in CC treatment, while those in CR treatment were 87.46 mg kg\(^{-1}\) d\(^{-1}\) (both showed promotion). With the growth of corn (June 17), the promotion rates of soil nitrification and N mineralization showed a promoting effect with continuous cropping and rotation treatments. The numbers of CR treatments were 37.33 and 38.13 mg kg\(^{-1}\) d\(^{-1}\) and those of CC treatment were 28.81 and 14.38 mg kg\(^{-1}\) d\(^{-1}\), respectively. The rates of nitrification and N mineralization in the later stage of maize growth (July 15) of CR were respectively 20.26 and -17.18 mg kg\(^{-1}\) d\(^{-1}\), respectively, which showed inhibition, while those of CC treatment were 7.17 and -4.00 mg kg\(^{-1}\) d\(^{-1}\) respectively, which showed a promotion effect. The highest rate of nitrification and N mineralization appeared in the early stage of maize growth (May 20), and decreased with the delay of maize growth until the late growth stage, where showed inhibition. The highest rate of nitrification and N mineralization under continuous cropping were observed during the mid-maize growth period (June 17), and gradually decreased with the delay of maize growth. However, it had a promoting effect and only showed inhibition in the early stage of maize growth (May 20). The results showed that mineralization of N in maize field was earlier under crop rotation than that under continuous cropping, while the continuous cropping could make the promotion of N mineralization longer than crop rotation.

Relationship between Soil Net N Mineralization Rate and Change in Soil Moisture

The net N mineralization rates of all treatments in corn fields were negatively correlated with soil moisture (Table 4). The R\(^2\) of the trend line of CK, CR and CC for the relationship between net N mineralization rate and soil moisture were 0.854, 0.994 and 0.627, respectively. Correlation coefficients of CK and CR in crop rotation were -0.942 and -0.997, respectively of which CR treatment reached a significant level of 0.05. The correlation coefficient of CC treatment in continuous cropped corn field was -0.791, which did not reach 0.05 significant level. The net N mineralization rate of corn field decreased with the increase of soil moisture, and the net N mineralization rate of crop rotation field was closely related to soil moisture.
However, according to the changes of microenvironment, the farmland development, the N mineralization rate increased, which further verified the argument (Anikwe et al., 2003; Wei et al., 2008). The results of this study also showed that during the whole growth period of corn, the net ammonification rate was highest in rotation. At the middle stage of corn growth, the net nitrification rate and net mineralization rate of rotation were higher than those of continuous cropping. At the later stage of corn growth, net nitrification rate and net N mineralization rate of continuous cropping were higher than those of rotation. This indicated that the rotation was conducive to increase the rate of net ammonification in corn field and the N mineralization of crop rotation was higher than that of continuous cropping. Therefore, the soil with rotation could convert a large amount of soil N into inorganic N earlier for crop demand. The main reason is that the process of soil net N mineralization is also affected by the comprehensive effects of other factors such as soil physical and chemical properties (Guntias et al., 2012). Moreover, the farmland cultivation can also cause changes in soil microenvironment (Bronick and Lal, 2005), due to continuous cropping obstacles caused by continuous cropping (Liu et al., 2014), Crop rotation and cropping.
systems have different effects on crop growth and development, which indirectly affecting the accumulation and decomposition of soil organic matter and the relationship among fertilizer N, soil N and crop N uptake, resulting in nitrification and denitrification process being affected (Mosier et al., 1990; Wang et al., 2008).

Soil net N mineralization process is affected by the soil microorganisms (Anikwe et al., 2007; Chaparro et al., 2013). Since the crop during transplanting is in the seedling stage, its root secretion capacity and the microbial activity is weak; the reason for no obvious N mineralization. With crop growing and developing in the reproductive growth stage, strong root exudation of crop increases microbial activity as well as N mineralization ability (Chaparro et al., 2013; Liu et al., 2016b). The impact of root exudates on microbial activity plays an important role. Possible root secretion impact on microbial activity also plays an important role, still need further study.

The results of this study showed that during the base fertilizer of corn (May 20), the crop rotation showed promotion and reached the highest, while the continuous cropping was inhibited. At the vigorous growth stage of corn (June 17), continuous cropping and rotation of corn fields all showed the promotion effect, during which the promoting effect of continuous cropping corn field reached its highest. At late corn growth stage (July 15th), continuous cropping was promoted and rotation was inhibited. This indicated that rotation contribute to earlier N mineralization in the corn field. The promotion rates of nitrification and N mineralization in rotation were higher than those in rotation by 3.04 and 6.08 times, indicating that rotation could enhance soil N mineralization in the corn field. The reason is that in the process of agricultural production, the physical and chemical properties of farmland soil are affected by different farming practices (Hou et al., 2012; Wang and Li, 2014; Li et al., 2015), and the continuous cropping pattern can make soil porosity smaller (Majeed et al., 2012). Some researchers believe that change of soil pore size will affect the period and process of soil solution retention, thus impeding the mineralization of N in the soil (Pan et al., 2016). Therefore, the rotation can improve and advance the ability of N mineralization in corn field. However, it needs to be further verified.

Nitrogen transformation in soil is caused by microbial activity, and soil moisture is the main factor that affects microbial activity. The main water source of farmland in the Southwest Yellow area is rainfall. It has been reported (Hübner et al., 1991; Liu et al., 2007) that in the range of 5 ~ 25°C, the net N mineralization rate increases with the increase of soil moisture, and the net mineralization rate of N and soil moisture has a positive correlation. The results of this study showed that there was a negative correlation between net N mineralization rate and soil water content in corn fields, which was inconsistent with previous results. As can be seen from Fig. 1, a temperature higher than 25°C occurred several times in this study, which may be the dominant effect of this result. This further confirmed that temperature has influence on soil net N mineralization (Wang et al., 2004).

Conclusion

N mineralization is mainly in the later stage of crop growth, while the early crop growth is N fixation. The net ammonification rate, net nitrification rate and net N mineralization rate were the highest in late crop growth stage, and the net ammonification rate in crop rotation was higher than that in continuous cropping. Net nitrification and N mineralization in continuous cropping were higher than those in crop rotation. Rotation in the yellow soil area can promote N mineralization. Under continuous cropping and rotation cultivation of corn in yellow soil area, the net N mineralization rate of corn was negatively correlated with soil water content. The net nitrogen mineralization rate was related to soil water content in the fertilized + rotation maize field.

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