INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
18F–005/2018/20–5–1175–1180
DOI: 10.17957/IJAB/15.0646
http://www.fspublishers.org

Full Length Article

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

Jiang Yuzhou[1], Liu Qingli[2*], Zhang Yungui[2], Li Zhihong[2], Zou Yan[3], Zhu Jingwei[3], Shi Junxiong[3] and Wang Peng[1]
[1]*Agronomy College of Heilongjiang Bayi Agricultural University, China*
[2]*Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Heilongjiang, China*
[3]*Tobacco Science Institute of Guizhou Province, China*
[*]For correspondence: 417313576@qq.com; silvia_201288@hotmail.com

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 (Qixiao, 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).

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-hydrolyzableN 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%, P_2O_5 4%), calcium superphosphate 407 $kg.hm^{-2}$ (P_2O_5 14%) and potassium sulfate 118 $kg.hm^{-2}$ (K_2O 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 hm^{-2}. 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 NH_4^+-N and NO_3^--N were measured by a continuous flow analyzer (Flastar 5000 Analyzer) (Bao, 2000).

Calculation and Data Analysis

$$\text{Net N mineralization rate of soil} = \frac{(\text{amount of mineralized N after cultivation} - \text{amount of mineralized N before cultivation})}{\text{days of cultivation}}$$

$$\text{Net nitrification rate of soil} = \frac{(\text{amount of nitrate N after cultivation} - \text{amount of nitrate N before cultivation})}{\text{days of cultivation}}$$

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

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

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

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 them 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

Improved nitrification 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. A 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 a delay of maize growth. However, it had a promoting effect and only showed inhibition in the early stage of maize growth (May 20). Data showed that mineralization of N in maize field was earlier under crop rotation than that under continuous cropping, while the continuous cropping promoted the 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.

Table 1: Fertilizer rate of different treatment process ($kg.hm^{-2}$)

Treatment	Fertilizer application rates ($kg.hm^{-2}$)				
	Basal fertilizer			Top fertilizer(1)	Top fertilizer(2)
	N	P_2O_5	K_2O	N	N
CK	0	0	0	36	60
CR	24	60	60	36	60
CC	24	60	60	36	60

Table 2: Effects of continuous cropping and crop rotation treatments ammonification, nitrification and N mineralization rates in maize yellow soil

Treatment	Net ammonification rate ($mg.kg^{-1}.d^{-1}$)		
	20-May	17-Jun	15-Jul
a. Net ammonification rates			
CK	0	-0.09±0.03 b	0.15±0.01 a
CR	0	-0.13±0.04ab	0.15±0.01 a
CC	0	-0.13±0.05 a	0.12±0.01 b
b. Net nitrification rates			
CK	-0.23±0.04 b	0.69±0.05 b	0.83±0.01 a
CR	-0.42±0.03 c	0.73±0.08 b	0.69±0.02 b
CC	-0.03±0.01 a	1.02±0.13 a	0.70±0.05 b
c. Net N mineralization rates			
CK	-0.23±0.04 b	0.59±0.03 b	0.98±0.01 a
CR	-0.42±0.03 c	0.60±0.01 b	0.84±0.02 b
CC	-0.03±0.01 a	0.89±0.08 a	0.83±0.05 b

Mean ± standard deviation. Values sharing same letters differ non-significantly (P>0.05)

Table 3: Effects of continuous cropping and crop rotation treatments nitrification and N mineralization promotion rate in maize yellow soil

Treatment	Nitrification promotion rate（%）			Nitrogen mineralization promotion rate（%）		
	20-May	17-Jun	15-Jul	20-May	17-Jun	15-Jul
CK	-	-	-	-	-	-
CR	87.46	37.33	-20.26	87.46	38.13	-17.18
CC	-81.62	28.81	7.17	-81.62	14.38	4

Discussion

Organic N is the main form of soil N, and is the source and reservoir of mineral N. Therefore, soil N supply is the overall performance of mineralization of different organic N components in soil. The N mineralization process of transforming soil organic N into mineral N is necessary for plant accessing to Nnutrients (Dehua *et al.*, 2003; Wei *et al.*, 2008). The results of this experiment showed that soil N is fixed during crop transplanting stage. With the crop growth and development, the N mineralization rate gradually increased, which further verified the argument (Anikwe *et al.*, 2007). However, according to the changes of mineral N components, the soil ammonification process did not show during the transplanting period (May 20), the N fixation was dominant among all treatments.

Table 4: Dependence of net N mineralization rates ($mg.kg^{-1}.d^{-1}$) on soil water of continuous cropping and crop rotation treatments in maize yellow soil

Treatment	Regression equation (y = ax + b)	*r*	R^2
CK	y = -1.1788x + 0.3383	0.924	0.854
CR	y = -2.5247x + 0.6579	0.997	0.994
CC	y = -0.5678x + 0.1771	0.791	0.627

r= correlation coefficient
R^2 = Coefficient of determination
y= net N mineralization rates ($mg.kg^{-1}.d^{-1}$)
x= soil water

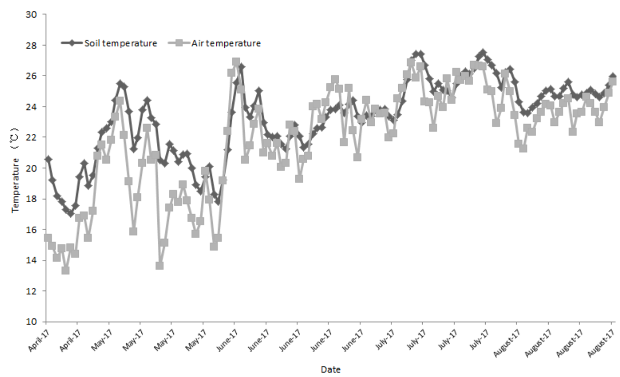

Fig. 1: Seasonal variations of air temperature and soil temperature from maize field

In the middle stage of crop growth (June 17), the mainly N mineralization were dominant among all treatments, in which the rate of net ammonification was negative. In the late growth stage (July 15), the rates of net ammonification, net nitrification and net N mineralization reached the highest, ranging from 0.12–0.15, 0.69–0.83 and 0.83–0.98 $mg.kg^{-1}.d^{-1}$, respectively.

The 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 was at the seedling stage, its root secretion capacity and the microbial activity were weak. This is 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 at its highest. At late corn growth stage (July 15^{th}), 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 (Hủbner *et al*., 1991; Liu *et al*., 2007) that in the range of 5 ~ 25℃, 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℃ 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.

Acknowledgements

This work is supported by "Evaluation on Carbon-nitrogen Circulation and Ecological Value of Tobacco-soil System" (110201402015), a science and technology program of China National Tobacco Corporation. I would express my gratitude to all those who have helped me during the writing of this thesis. I gratefully acknowledge the help of my supervisor Professor Wang Peng. I do appreciate her patience, encouragement, and professional instructions during my thesis writing.

References

Anikwe, M.A.N., C.N. Mbah, P.I. Ezeaku and V.N. Onyia, 2007. Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (*Colocasia esculenta*) on an ultisol in southeastern Nigeria. *Soil Till. Res*., 93: 264–272

Aulakh, M.S. and B. Singh, 1997. Nitrogen losses and fertilizer N use efficiency in irrigated porous soils. *Nutr. Cycl. Agroecosys*., 47: l97–2l2

Bao, 2000. *Soil Agricultural Analysis*. China Agriculture Press, Beijing, China

Bronick, C.J. and R. Lal, 2005. Soil structure and management: A review. *Geoderma*, 124: 3–22

Chaparro, J.M., D.V. Badri, M.G. Bakker, A. Sugiyama, D.K. Manter and J.M. Vivanco, 2013. Root exudation of phytochemicals in arabidopsis follows specific patterns that are developmentally programmed and correlate with soil microbial functions. *PloS One*, 8: 1–10

Dehua, M., J. Xia and Y. Huang, 2003. Study on some basic problems of ecological rehabilitation in northwest area. *J. Soil Water Conserv*., 17: 15–18

Guntias, M.E., M.C. Leirós, C. Trasar-Cepeda and F. Gil-Sotres, 2012. Effects of moisture and temperature on net soil nitrogen mineralization: A laboratory study. *Eur. J. Soil Biol*., 48: 73–80

Hou, X., R. Li, Q. Han, Z. Jia, W. Wang, B. Yang, J. Wang, J. Nie and Y. Li, 2012. Effects of alternate tillage on soil physicochemical properties and yield of dryland wheat in arid areas of south Ningxia. *Acta Pedol. Sin*., 49: 592–600

Hu, R., X. Wang, Y.X. Pan, Y.F. Zhang, K. Zhang and H. Zhang, 2014. Response of net soil nitrogen mineralization rate in moss-covered soil to hydrothermic factors in Shapotou regions, northern China. *Chin. J. Appl. Ecol.*, 25: 394–400

Hǜbner, C., G. Redl and F. Wurst, 1991. *In situ* methodology for studying N-mineralization in soils using anion exchange resins. *Soil Biol. Biochem.*, 23: 701–702

Li, Y.J., H. Wang, J.N. Zhao, C.H. Huangfu and D.L. Yang, 2015. Effects of tillage methods on soil physicochemical properties and biological characteristics in farmland: A review. *Chin. J. Appl. Ecol.*, 26: 939–948

Liu, M., C. Zhang and Y. He, 2016b. Impact of fertilization method on soil nitrous oxide emissions and ammonia volatilization during summer maize growth period. *J. Plant Nutr. Fert.*, 1: 19–29

Liu, X., S. Zhang and G. Liu, 2014. Effects of continuous cropping on dry matter accumulation and distribution of potato plants in the Yellow River irrigation areas of middle. *Acta Agron. Sin.*, 40: 1274–1285

Liu, X., Y. Dong, Y. Qi and D. Manfred, 2007. Soil net nitrogen mineralization in the typical temperate grassland. *Chin. J. Environ. Sci.*, 28: 633–639

Liu, Y., F. Ding and J. Zhang, 2016a. Effects of activated humic acid-urea on nitrogen use efficiency and its driving factors under wheat-maize rotation system. *Chin. J. Eco-Agric.*, 24: 1310–1319

Liu, W., Y. Gao and J. Wang, 2015. Effects of moisture factor on soil nitrogen mineralization in oasis-desert ecotone. *J. Soil Water Conserv.*, 29: 89–94

Majeed, M.Z., E. Miambi and A. Robert, 2012. Xylophagous termites: A potential sink for atmospheric nitrous oxide. *Eur. J. Soil Biol.*, 53: 121–125

Melillo, J.M., 1981. Nitrogen cycling in temperate deciduous forests. *Ecol. Bull.*, 33: 422–427

Mosier, A.R., S.K. Mohanty, A. Bhadrachalam and S.P. Chakravorti, 1990. Evolution of dinitrogen and nitrous oxide from the soil to the atmosphere through rice plants. *Biol. Fert. Soils*, 9: 61–67

Pan, J., S. Zhuang, H. Huang, X. Chen, Z. Shi and Z. Cao, 2016. Effect of inorganic amendments on nitrogen mineralization in red soil with tobacco plantation in south Anhui. *J. Soil Water Conserv.*, 30: 193–199

Qixiao, W., 1992. *Soil Nitrogen Content, Morphology and ^{15}N Abundance-Nitrogen in Soils of China*. Jiangsu Science and Technology Press, Nanjing, China

Wang, C., X. Xing and H. Xingguo, 2004. The effects of temperature and moisture on the soil net nitrogen mineralization in an *Aneulolepidium chinensis* grassland, Inner Mongolia, China. *Acta Ecol. Sin.*, 24: 2472–2476

Wang, L.G., H. Li and J.J. Qiu, 2008. Characterization of emissions of nitrous oxide from soils of typical crop field in Huang-Huai-Hai Plain. *Sci. Agric. Sin.*, 41: 1248–1254

Wang, Y. and J. Li, 2014. Study on tillage methods benefit soil physical and chemical properties and crop yields of wheat-corn rotation field. *J. Plant Nutr. Fert.*, 5: 1139–1150

Wei, Q., Q.L. Zhang, H.Y. Dai and X. Guo, 2008. Soil characteristics and water conservation of different forest types in Daqing mountain. *J. Soil Water Conserv.*, 2: 111–115

Yan, M., 2013. *Effects of Different Cropping Patterns of Soybean and Maize Seedlings on Root Zone Soil Carbon and Nitrogen Mineralization in Stage*. Northeast Agric. University, China

Zhu, J., Q. Wang, N. He and J. Dai, 2013. Soil nitrogen mineralization and associated temperature sensitivity of different inner Mongolian grasslands. *Acta Ecol. Sin.*, 33: 6320–6327

(Received 05 January 2018; Accepted 18 January 2018)