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Simulation of Soil Nitrogen Mineralization by Temperature and Water in a Typical Period of Forest Succession in the Central Subtropical Zone

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Key words: middle subtropical zone; forest succession; temperature; water; nitrogen mineralization

Abstract: Indoor undisturbed soil column incubation experiment with PVC tube was conducted by choosing 3 typical stages of shrub, coniferous forest and broadleaf forest as the research objects, and setting 3 different temperatures (12^{o}C, 24^{o}C and 36^{o}C) and 3 different water conditions (soil natural water, semi saturated water and saturated water)to conduct completely randomized experiment for 3 times with 3 factors and 3 levels, in order to estimate the effect of temperature, moisture and their interaction on nitrification and mineralization rate of soil ammonification in tropical Asia area.

Introduction

The study of forest succession and disturbance of forest ecosystem restoration provides a very important theoretical basis for the conservation and ecological management of forest resources (Leuschner & Rode, 1999). The continuous regeneration of species and the change of their social conditions are the main driving forces of forest succession. Meanwhile, the succession of vegetation species and communities has led to the process of vegetation restoration (Zhang et al., 2005). The availability of soil nitrogen (N) has positive effects on the succession of forest communities（Li G C，2001）.Nitrogen is the main limiting factor in plant growth, and the availability of nitrogen is closely related to the primary productivity of vegetation (Reich et al., 1997).Nitrogen mineralization, i.e., the conversion of organic nitrogen to inorganic nitrogen, mainly determines the availability of nitrogen (Wang et al., 2006).On the microclimate of the soil (temperature, moisture) and effects of their interaction on nitrogen mineralization is helpful for us to further understand the mechanism of soil nitrogen mineralization and nitrogen effectiveness of forest succession under the ecological system. The mineralization of soil organic matter depends on itself and climatic factors. Provided with certain temperature and humidity, the soil microbes will play their maximum activity, which makes the maximum of nitrogen mineralization (Leiros et al., 1999).Sierra (1997) found that the effect of temperature on nitrogen mineralization was stronger than that of humidity. There are many reports can be found about the effects of temperature and humidity on nitrogen mineralization both home and abroad. (Sierra, 1997; Cookson et al., 2007; Dalias et al., 2002; Quemada & Cabrera, 1997; Myers et al., 1982), but it's unclear how temperature and humidity as well as the interaction between them have effects on nitrogen mineralization soil under different stages of forest succession.

This research is mainly got by the methodology of laboratory aerobic cultivating, artificially adding moisture and controlling temperature, thus conduct a more comprehensive study of the temperature effect of nitrogen in different stages of mineralization of soil moisture and their interaction on forest succession.

Materials and Methods

The 3 typical stages in this study were selected from Jiangxi Agricultural University, including, shrub forest, pinus massoniana forest, and broad-leaved forest.

Indoor undisturbed soil column incubation experiment with PVC tube was conducted. Choosing 3 typical stages of shrub, coniferous forest and broadleaf forest as the research objects, setting 3 different temperatures (12^{o}C, 24^{o}C and 36^{o}C) and 3 different water conditions (soil natural water, semi saturated water and saturated water), conduct completely randomized experiment for 3 times with 3 factors and 3 levels. Three samples were selected for each stage of succession, and the undisturbed soil was taken in PVC plots. In each plot, 1 PVC tubes were first driven into the soil, and the soil was then driven into the soil with 9 PVC tubes, which were later taken to the laboratory for analysis. The initial soil content of NH^{+}_{4}-N and NO^{-}_{3}-N each sample was analyzed, with the other undisturbed soil columns remained in the PVC, to keep in the laboratory incubator for further culture under controlled temperature and soil moisture. After 30 days of culture, all the soil columns were taken for NH^{+}_{4}-N and NO^{-}_{3}-N content analysis to determine the ammonification, nitrification and net mineralization rate of nitrogen.

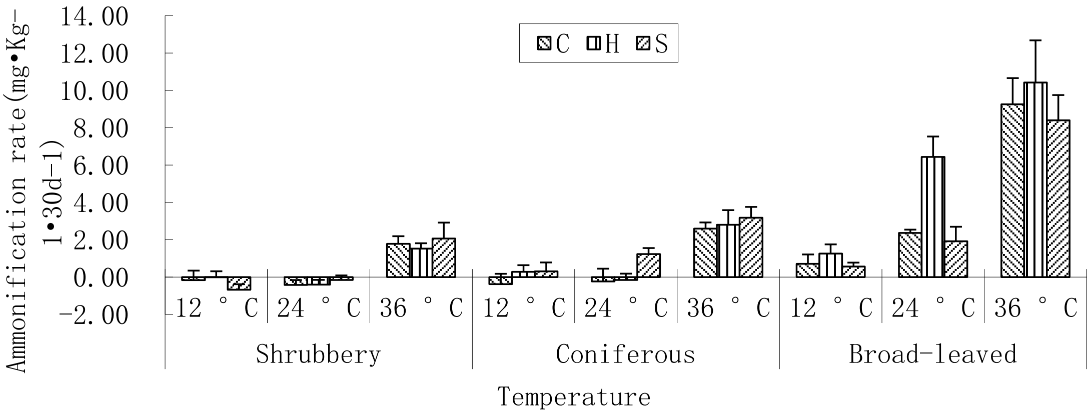
Do statistical analysis with SPSS 11 (SPSS 2001).Single factor analysis of variance was applied to analyze the physical and chemical properties of soil, multivariate analysis of variance was applied to analyze the effects on the rate of ammonification, nitrification and mineralization with the three factors, including water, temperature and succession stage.

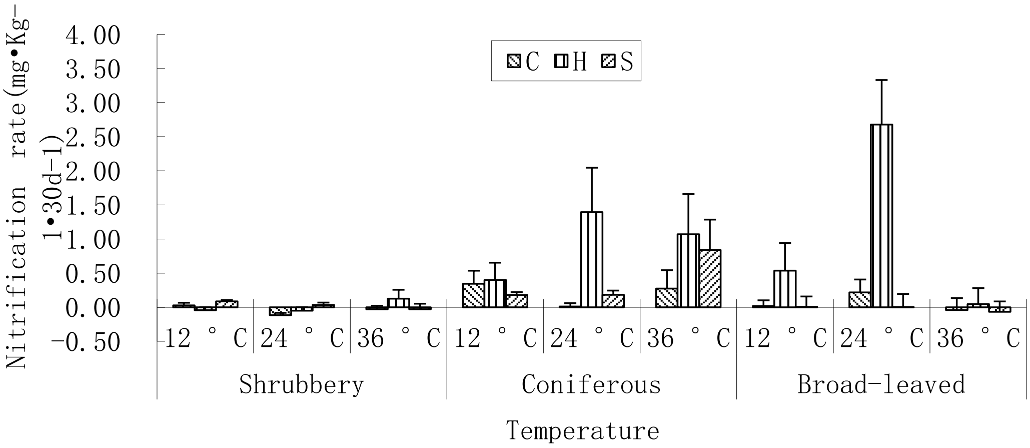
Results

As it can be seen from table 1, the effect of temperature and succession stage on soil ammonification rate is very significant ($P < 0.01$), and the effect of water content on ammonification rate is not significant ($P > 0.05$).From the effect of interaction, except for the rate of soil ammonification by the interaction of temperature and succession stage, and the interaction of water and succession stage, the others are not significant. Fig. 6-1 the ammonification rate increased along with forest succession direction, as it shows broad-leaved forest (4.59 mg·kg^{-1}·30 d^{-1}), coniferous forest (1.07 mg·kg^{-1}·30 d^{-1}), shrub forests (0.39 mg·kg^{-1}·30 d^{-1}).For the effect of temperature, there is a positive correlation between the ammonification rate and temperature, it becomes larger with the increase of temperature, showing12 ^{o}C（0.21 mg·kg^{-1}·30 d^{-1}）<24 ^{o}C（1.17 mg·kg^{-1}·30 d^{-1}）<36 ^{o}C（4.67 mg·kg^{-1}·30 d^{-1}）(table2).From the effect of water on ammonification rate, the maximum value appears in the half saturated water content stage, but the overall effect is not significant. The maximum value of ammonification rate is10.42 mg·kg^{-1}·30 d^{-1}, which is the result of comprehensive action of the broad-leaved forest stage, under temperature of about 36 degrees C, and water in the half saturation state.

Table 1 Effects of temperature, water and succession stage on ammonification rate, nitrification rate and net mineralization rate.

Factor	Freedom	Ammonification rate		Nitrification rate		mineralization rate	
		F	*P*	F	*P*	F	*P*
Temperature	2, 54	87.58	0.000	1.86	0.166	59.08	0.000
Water	2, 54	2.43	0.098	7.81	0.001	5.68	0.006
Succession stage	2, 54	80.88	0.000	5.06	0.010	60.99	0.000
Temperature×Water	4, 54	0.43	0.788	3.01	0.026	1.4	0.247
Temperature×Succession stage	4, 54	16.61	0.000	2.76	0.037	10.04	0.000
Water×Succession stage	4, 54	3.68	0.01	2.28	0.073	4.31	0.004
Temperature×Water×Succession stage	8, 54	1.01	0.378	1.37	0.229	1.42	0.21





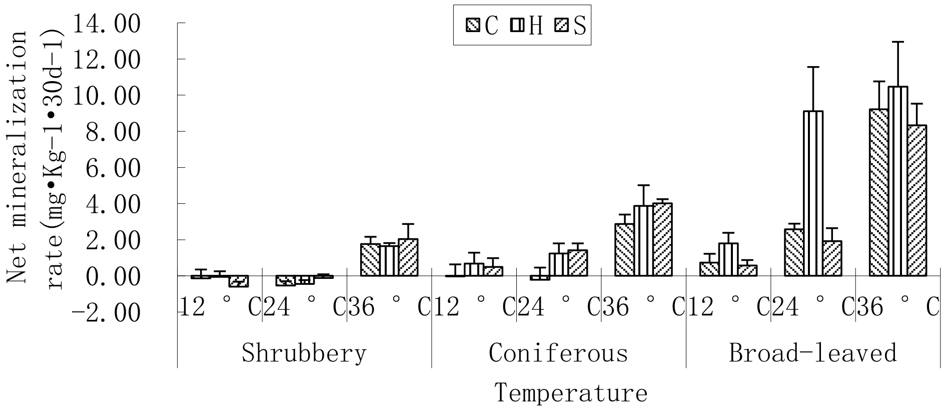


Fig. 1 Variation of soil ammonification rate, nitrification rate and mineralization rate under different temperature, water and soil samples

As it can be seen from table 1, the effects of water and succession stages on soil nitrification rate are significant ($P < 0.05$).However, the effect of temperature isn't. ($P > 0.05$).Except for the interaction of temperature and moisture, the interaction of temperature and succession stage, the other interactions are not significant. At first, the effect of different moisture on nitrification performance increases but later decreases (Figure 1), and the maximum value appears in the semi saturation state (0.68 mg·kg^{-1}·30 d^{-1}) which is significantly higher than that of soil natural water and water saturated state (Table 2).From the aspect of influence of successional stages, the soil nitrification rate of coniferous forest under the maximum (Figure 1), is 0.52 mg·kg^{-1}·30 d^{-1}, which is significantly higher than that of shrub forest soil (0 mg·kg^{-1}·30 d^{-1}), but is similar to broad-leaved forest soil. As for the temperature effect, the maximum value appears at 24^{o}C level, with 0.48 mg·kg^{-1}·30 d^{-1}, slightly larger than the level at the12^{o}C and 36^{o}C (Table 2).

Table 1 shows that the effects of temperature, moisture and succession stages on soil nitrogen mineralization rate are extremely significant. The interaction effects are as follows: interaction of temperature and succession, and interaction of water and succession are significant, but the temperature and moisture, as well as the interaction among temperature, moisture, and succession of nitrogen mineralization are not significant. From Figure 1, we can determine the soil nitrogen mineralization rate under different temperatures, moistures and soil samples is similar to the rate of soil ammonification. The maximum mineralization rate of nitrogen occurred in the broad-leaved forest stage, with the temperature of 36^{o}C and the water content of 10.46 mg·kg^{-1}·30d^{-1}.The minimum mineralization rate under different temperatures appeared at 12^{o}C level, which0.38 mg·kg^{-1}·30 d^{-1}, and the maximum mineralization rate under different temperatures appeared at 36^{o}C, which is4.91 mg·kg^{-1}·30 d^{-1}.The same maximum value of soil water effect is found in the semi saturated water phase, which is 3.14 mg·kg^{-1}·30 d^{-1}, significantly higher than that in natural water and saturated water phase. The soil mineralization rate differences are prominent in different successional stages, as bush (0.39 mg·kg^{-1}·30 d^{-1}) than coniferous forest (1.59 mg·kg^{-1}·30 d^{-1}) than broad-leaved forest (4.97 mg·kg^{-1}·30 d^{-1}) (Table 2).

Table 2 The rate of ammonification, nitrification rate and net mineralization rate under different treatments

	Treatment	Ammonification rate	Nitrification rate	Netmineralization rate
Temperature	12°C	0.21±0.16 a	0.17±0.06 a	0.38±0.19 a
	24°C	1.17±0.44 b	0.48±0.23 a	1.66±0.61 b
	36°C	4.67±0.73 c	0.24±0.11 a	4.91±0.72 c
Water	Natural water	1.72±0.59 a	0.08±0.05 a	1.80±0.6 a
	Semi saturated water	2.46±0.72 a	0.68±0.23 b	3.14±0.82b
	Saturated water	1.87±0.54 a	0.14±0.07 a	2.00±0.53 a
Succession stage	Bush	0.39±0.23 a	0.00±0.02 a	0.39±0.23 a
	Coniferous forest	1.07±0.3 a	0.52±0.13 b	1.59±0.25 b
	Broad-leaved forest	4.59±0.8 b	0.38±0.22 ab	4.97±0.86 c

Note: The average value of the standard error, the same column with the same letter indicates that the difference is not significant, the difference is significant ($p<0.05$)

Discussion

The transformation of soil nitrogen mainly includes the biological process affected by temperature (Dalias et al., 2002).Wang et al. (2006) indicated that there is a significant positive correlation between nitrogen mineralization and culturing temperature. The results show that the mineralization rate of soil nitrogen increases exponentially with the increase of temperature, which is similar to the previous reports (Sierra, 1997; Dalias al., et; et; Wang al., 2006).It's considered that the increase of temperature resulted in an increase of nitrogen mineralization is connected with the larger existence of microbial nitrogen mineralization (Hoyle et al., 2006).As it can be seen from table 2, the ratio of ammonification rate on mineralization rate increases with the temperature, such as, the ammonification rate at 12°C, accounting for 55%; at 24°C, accounting for 70%; at 36 °C, accounting for 95%, which indicates that increase of temperature greatly promotes the process of ammonification, but the influence of nitrification isn't, and even in some degree, it takes an inhibitory effect. The reasons for this result may be: 1. Cookson et al. (2007) concluded that the increase in the release of $NH4^+$ is due to the availability of dissolved organic N (DON) resulted by an increase in the demand for microbial C.2. The result of this study shows that the effect of temperature on nitrification rate is not significant, so it is possible that the nitrification in soil is relatively low in the middle subtropical region or the soil nitrifying bacteria isn't sensitive to the temperature fluctuation.

The availability of water controls the activity of soil microorganisms, thus controlling the mineralization rate of nitrogen (Nicolardot et al., 1994; Stark and Firestone, 1996).When the water content reaches the maximum of soil moisture capacity, the nitrogen mineralization rate is the largest(Stanford et al.,1972;Wang et al., 2006). Quemada&Cabrera (1997)'s study shows that the maximum value of nitrogen occurs when the mineralization rate is between -0.3 and -0.1 Mpa, and the water content is 10% to 35%.The study finds that the ammonification rate, nitrification rate and mineralization rate in the initial stage increases with the increase of the soil moisture when the semi saturated water stage reaches the maximum value, but later it decreases with the water content increasing. This is mainly because biological activity is the strongest and the most exuberant when the soil moisture is in the semi saturated, however, when the water moisture is in anaerobic condition, it is not conductive for microbial growth and reproduction. As it can be seen from table 3, the nitrification rate and mineralization rate are significantly higher than that of natural water content and saturated water content in the soil when the soil moisture is half saturated. When the soil moisture exceeds a certain range, the activity of denitrifying bacteria increases gradually, which led to the denitrification of NO^-_3 intoN_2O andN_2 (Rice et al., 1988; Susana Bernal, 2007).

Effects of Forest Succession on N Mineralization

In China, the research on the relationship between forest succession and nitrogen transformation is relatively less. The results shows that there is a positive correlation between nitrogen mineralization rate and forest succession. This is mainly due to the gradual decline of C/N, which is from 37.07 to 9.12 (table 2-1). Litteringsnitrogen is negatively correlated with C/N. The higher the organic matter (i.e., high C/N) produces in the barren plots, the slower of nitrogen mineralization rate will be (Vitousek et al., 1982).And the results of this study are contrary to the results of CLEIN & SCHIMEL (1995)The results shows that the soil nitrogen mineralization rate in the later succession stage is lower than that in the previous succession stage. The result of the research may be caused by different characteristics of different vegetation succession process and different environmental conditions, because the litter decomposition is the basis of terrestrial ecosystem snutrient cycle, and its process is strongly influenced by litter properties and environmental conditions (Xu Xiaojing, 2007).

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