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Dynamics of Soil NH_4^+-N and NO_3^--N in Rubber Plantation in Wenchang, South China

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Abstract

In this study, the dynamics of soil available nitrogen in rubber plantations was studied to provide a basis for the sustainable management of soil nutrients in rubber plantations. Soil samples were collected from 0 - 20 cm and 21 - 40 cm depth of rubber plantations in Wenchang area of Hainan Province to determine the soil ammonium nitrogen and nitrate nitrogen in March, June, September and December. The results showed that the total available nitrogen in the rubber plantation soil was mainly composed of nitrate nitrogen (>57%), and this nitrate nitrogen was always the absolute composition advantage in the total available nitrogen composition, and this composition advantage did not change with the change of soil depth. Nitrate and ammonium nitrogen in rubber plantation soil showed obvious seasonal variation characteristics in 0 - 20 cm soil layer and 21 - 40 cm soil depth. With the seasonal time change, the contents of soil nitrate and ammonium nitrogen increased first and then decreased. Summer and autumn were the most active periods of soil nitrate and ammonium nitrogen. There was a significant positive correlation between soil nitrate nitrogen content and ammonium nitrogen content (r = 0.6532**). Based on the correlation between soil ammonium nitrogen content and nitrate nitrogen content, the content of ammonium nitrogen in soil can be estimated according to the amount of soil nitrate nitrogen.

Keywords

Rubber Tree (*Hevea brasiliensis*), Soil NH_4^+-N, soil NO_3^--N, Wenchang, Correlation

1. Introduction

Nitrogen, together with light, temperature and rain, is an important environmental factor affecting the growth and development of agricultural and forestry plants [1]. In plant soil, nitrogen is an indispensable nutrient element in the process of plant growth and development. It is also the nutrient and mineral element with the largest demand from the soil environment. The nitrogen in the soil can be divided into organic nitrogen and inorganic nitrogen, and most of the soil is organic nitrogen. This organic nitrogen can be directly absorbed by plants only through the mineralization of nitrogen and converted into inorganic available nitrogen use [2]. Therefore, the study of soil nitrogen is of great significance for understanding the nitrogen cycle relationship and system productivity among species composition units in agroforestry ecosystem. However, the research on the dynamics of soil nitrate nitrogen and ammonium nitrogen has been paid attention to the industry. In the actual production, the utilization rate of nitrogen fertilizer is not high, and the applied chemical fertilizer is lost in various ways. Ammonia volatilization, nitrification, denitrification loss and leaching are all important ways of nitrogen loss [3] [4]. Although nitrogen is so important for plant growth and development. However, there are still some deficiencies in the study of the dynamics of soil inorganic available nitrogen, especially the relationship between nitrate nitrogen and ammonium nitrogen.

As an important economic forest tree species, rubber tree has been widely cultivated in tropical regions of the world [5] [6]. However, there are still some problems in soil nutrient management of rubber plantations, such as soil erosion, soil fertility and quality degradation, and unstable system structure [7] [8] [9]. Rubber plantation is prone to loss of soil nitrogen and decrease of soil nutrient utilization rate if human disturbance is improper compared with tropical rain forest [10]. Due to the strong mobility of nitrogen, temperature, rainfall and human disturbance will cause the migration and transformation of nitrogen in soil. The total amount of nutrient loss in rubber plantation system with the increase of tapping intensity is increasing, and the loss of nitrogen is the most [11]. However, the effect of rubber growth on the change of nitrogen forms in soil is not clear. The study on the change of available nitrogen in soil of rubber plantation is helpful to understand the migration and transformation of nitrogen in rubber forest system. Taking rubber plantation as the research object, the dynamic changes of soil available nitrogen (nitrate nitrogen, ammonium nitrogen) and the relationship between them were analyzed. This study provided a basis for further understanding of nitrogen cycle, nutrient relationship and system productivity of rubber plantation.

2. Materials and Methods

2.1. General Situation of Test Area and Sample Plot Setting

The experimental site was set up in the third section of the second group of Wenchang Rubber Institute (19˚20'N - 20˚10'N, 108˚21'E - 111˚03'E) in Wenchang, Hainan Province, South China. The experimental site belongs to tropical island monsoon climate, with typical and representative characteristics of Hainan land.

The annual average temperature is 23˚C, the annual average rainfall is 1721 mm, and the annual average humidity is 87%. The soil is mainly sandy loam soil with pH value below 6.5, which is slightly acidic. The age of rubber forest is 7 years old, the spacing of plant and row is 3 m × 7 m, and the conventional tending management is adopted.

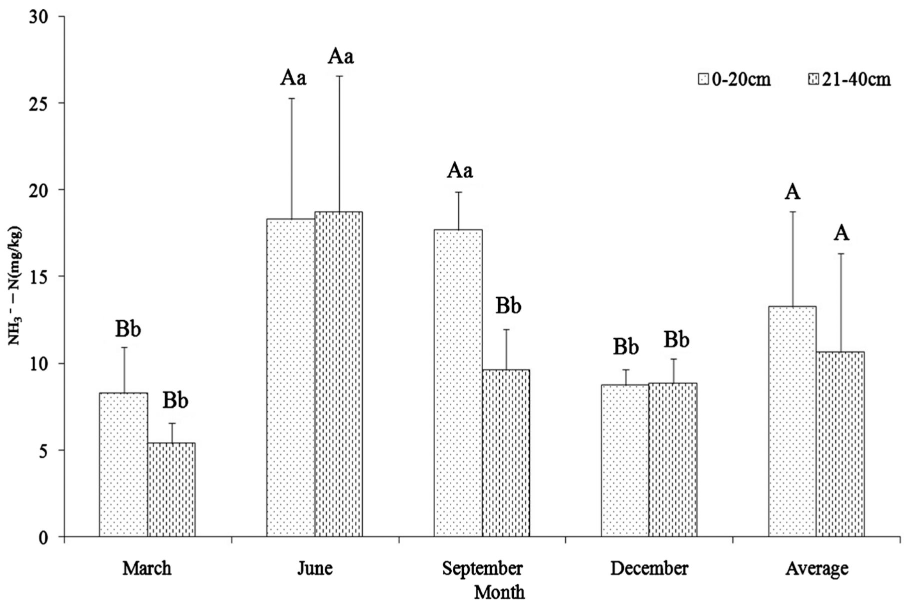
2.2. Research Method

The average number of rubber trees in each sampling plot was 50 and there are three sampling plots. The sampling period was March, June, September and December. Sampling method: adopt ring knife stratified sampling method. Soil samples are collected from 0 - 20 cm and 21 - 40 cm soil layers of sampling points respectively, and mix the soil of the same soil layer evenly, pick out the impurities and roots inside, and quickly take them back to the laboratory, and conduct soil nutrient analysis after air drying. Soil ammonium nitrogen was determined by KCI extraction indigo colorimetry, and soil nitrate nitrogen was determined by phenol disulfonic acid colorimetry. SPSS v21.0 and Excel 2007 were used for Duncan multiple comparison, multiple regression, correlation analysis, and mapping.

3. Results and Discussion

3.1. Change of Soil Nitrate Nitrogen Content in Rubber Plantation

The dynamic change of soil nitrate nitrogen content in rubber plantation is shown in Figure 1. It can be seen from Figure 1 that the content of soil nitrate nitrogen in rubber plantation tends to increase first and then decrease, showing



Note: capital letters represent differences between different soil layers, and lower letters represent differences between different months.

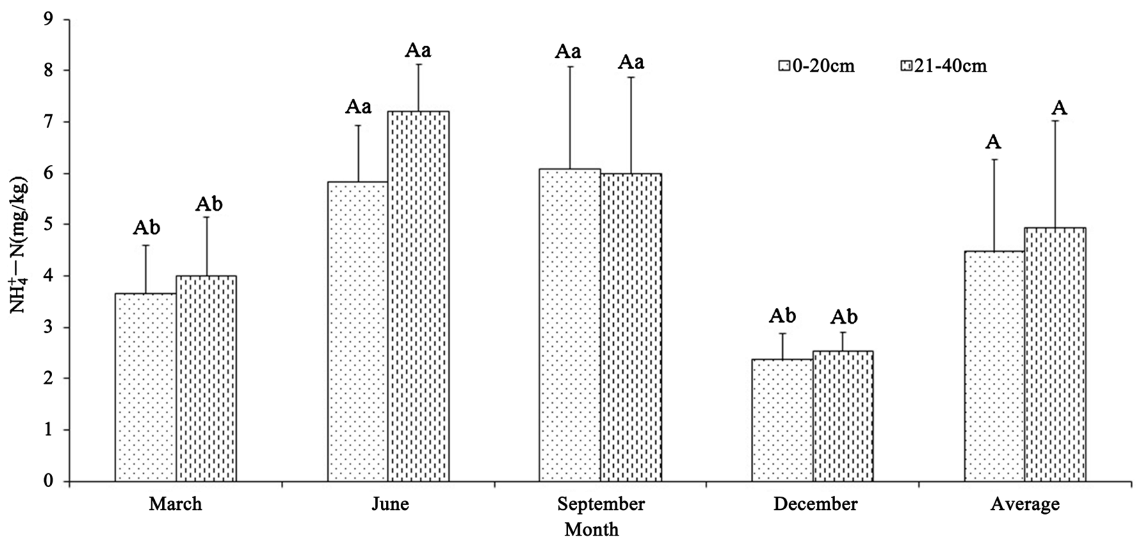
Figure 1. Dynamic changes of the soil NH_3^--N in rubber plantations.

obvious seasonal change, with the highest in June and the lowest in March. The range of nitrate nitrogen in rubber plantation soil was 8.29 - 18.31 mg/kg and 5.41 - 18.74 mg/kg in 0 - 20 cm and 21 - 40 cm soil layers, respectively. The average values of nitrate nitrogen in rubber plantation soil in 0 - 20 cm and 21 - 40 cm soil layers were 13.26 mg/kg and 10.65 mg/kg, respectively. The variation range of soil nitrate nitrogen in 21 - 40 cm soil layer tends to be higher than that in 0 - 20 cm soil layer, and the annual average value of soil nitrate nitrogen in 0 - 20 cm soil layer tends to be higher than that in 21 - 40 cm soil layer.

From different soil layers, the nitrate nitrogen content in June and September was higher than that in March and December in 0 - 20 cm and 21 - 40 cm soil layers, and the differences of nitrate nitrogen content reached a significant level. From the different sampling time, the content of soil nitrate nitrogen was the highest in June, followed by September and December, and the content of soil nitrate nitrogen was the lowest in March, showing obvious seasonal characteristics. This is basically consistent with the dynamic changes of soil ammonium nitrogen and nitrate nitrogen under rubber forest in Xishuangbanna, China [12]. In terms of other forests and artificial forests, they also have similar change rules. Li *et al.* [13] considered that the soil available nitrogen in the gap of *Pinus massoniana* plantation had seasonal change characteristics; soil ammonium nitrogen and nitrate nitrogen under different plant communities in wetland also had seasonal change characteristics [14].

3.2. Change of Soil Ammonium Nitrogen Content in Rubber Plantation

The dynamic change of soil ammonium nitrogen content in rubber plantation is shown in **Figure 2**. It can be seen from **Figure 2** that soil ammonium nitrogen



Note: capital letters represent differences between different soil layers, and lower letters represent differences between different months.

Figure 2. Dynamic changes of the soil NH_4^+-N in rubber plantations.

content of rubber plantation tends to increase first and then decrease, showing obvious seasonal change, with the highest in June and the lowest in December. The average values of ammonium nitrogen in 0 - 20 cm and 21 - 40 cm soil layers were 4.49 mg/kg and 4.94 mg/kg, respectively. The range of soil ammonium nitrogen in 21 - 40 cm soil layer tends to be higher than that in 0 - 20 cm soil layer, and the annual average value of soil ammonium nitrogen in 21 - 40 cm soil layer tends to be higher than that in 0 - 20 cm soil layer.

From different soil layers, the ammonium nitrogen in June and September in 0 - 20 cm and 21 - 40 cm soil layers was higher than that in March and December. From the different sampling time, the content of soil nitrate nitrogen was the highest in June, followed by September and December, and the content of soil nitrate nitrogen was the lowest in March. The difference of ammonium nitrogen in June and September with that in March and December reached a significant level, showing obvious seasonal characteristics. This seasonal variation is consistent with the results of some scholars [12] [13] [14] [15].

3.3. Composition Analysis of Soil Available Nitrogen in Rubber Plantation

Although there was seasonal variation of soil available nitrogen, total available nitrogen was mainly composed of nitrate nitrogen in each season (**Figure 3**). In 0 - 20 cm and 21 - 40 cm soil layers, the nitrate content of rubber plantation in different months accounted for more than 57%. Therefore, in this study, the total available nitrogen in the soil is mainly nitrate nitrogen, that is, in March, June, September, December, the total available nitrogen in the soil is mainly composed of nitrate nitrogen, and this nitrate nitrogen is always the absolute composition advantage in the total available nitrogen composition, and this composition advantage does not change with the change of soil depth. The study

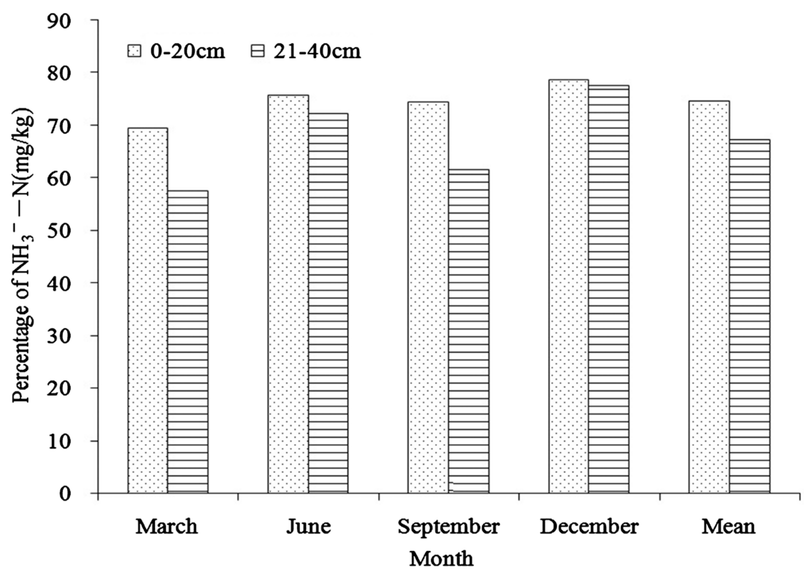


Figure 3. Percentage of NH_3^--N in the total available N in rubber plantations.

site located in the tropical monsoon climate with high temperature and rainy weather. The decomposition of organic matter in the soil may be strong in summer and autumn. The nitrification rate is much faster than the mineralization rate. The released ammonium nitrogen or the applied ammonium nitrogen fertilizer will quickly oxidize to nitrate nitrogen. Therefore, nitrate nitrogen is the main form.

3.4. Correlation Analysis of Soil Ammonium Nitrogen and Nitrate Nitrogen in Rubber Plantation

The correlation analysis of soil ammonium nitrogen and nitrate nitrogen content in different seasons and soil depths of rubber collar is shown in Figure 4. It can be seen from Figure 4 that the correlation coefficient between soil nitrate nitrogen content and ammonium nitrogen content is 0.6532 from March, June, September to December, reaching the extremely significant positive correlation level ($P < 0.01$, $P = 0.0005$). Under the action of nitrifying bacteria, the ammonium nitrogen in soil can be converted into nitrate nitrogen. When the content of ammonium nitrogen in soil is relatively high, the excessive ammonium nitrogen will be nitrated by nitrifying bacteria and transformed into nitrate nitrogen, resulting in a very significant positive correlation between soil ammonium nitrogen content and nitrate nitrogen content. Then, using the correlation between ammonium nitrogen content and nitrate nitrogen content ($y = 0.2141x + 2.1521$), the content of ammonium nitrogen in soil can be estimated according to the amount of nitrate nitrogen in soil. Mo *et al.* [16] also showed that there was a significant linear correlation between soil nitrate nitrogen and ammonium nitrogen in *Pinus massoniana* plantation.

Taking rubber plantation in Wenchang, South China as an example, the annual variation of available N in rubber plantation was studied, and whether the annual variation of available N in rubber plantation had similar change law needs to be further studied.

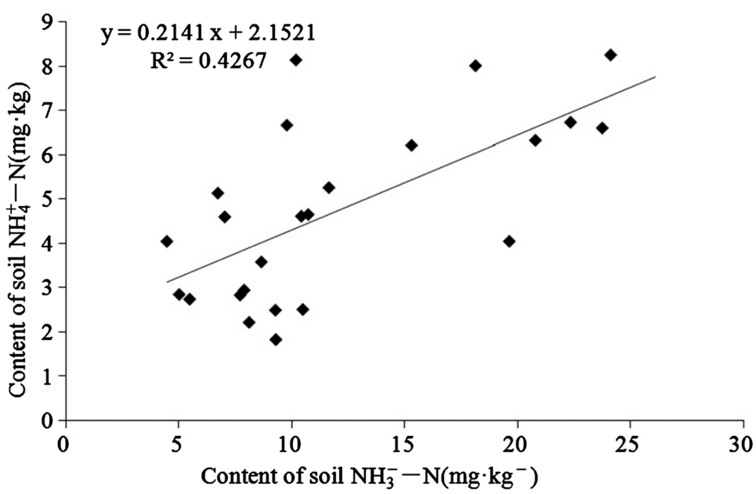


Figure 4. Relativity between NH_3^--N and NH_4^+-N in rubber plantations.

4. Conclusion

The soil nitrate and ammonia nitrogen of rubber plantation in Wenchang, Hainan Province have obvious seasonal changes. In June and September, that is, when the rainfall and heat are in the same season, the nitrate nitrogen and ammonium nitrogen in the soil are the most active period, and the contents of soil ammonium nitrogen and nitrate nitrogen are relatively high. There was a significant positive correlation between soil nitrate nitrogen content and ammonium nitrogen content ($r = 0.6532^{**}$). Based on the correlation between soil ammonium nitrogen content and nitrate nitrogen content, the content of ammonium nitrogen in soil can be estimated according to the amount of soil nitrate nitrogen. In different seasons and months, the total available nitrogen in soil was mainly composed of nitrate nitrogen, which was always the absolute composition advantage in the proportion of total available nitrogen, and this composition advantage did not change with the change of soil depth.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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