The Vertical Distribution Characteristics of Carbon to Nitrogen Ratio in Soft Rock and Sand Compound Soil

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Abstract. This study takes the soft rock and sand compound ratio communities located in Fuping, Shaanxi Province as the research object. Four treatments of soft rock and sand volume ratios of 0:1 (CK), 1:5 (C1), 1:2 (C2) and 1:1 (C3) were selected to analyze the relationship between carbon-nitrogen ratio (C/N) of compound soil and the soil nutrient and texture. The soil organic carbon and total nitrogen content decreased with the increase of soil depth under different treatments. The average organic carbon content ranged from 1.45-2.70 g·kg\(^{-1}\) and the organic carbon content of 0-10 cm soil layer was significantly higher than 20-30 cm soil layer, compounding ratio had a significant effect on organic carbon. With the increase of volume fraction of soft rock, the organic carbon content of 0-10 cm soil layer was the highest in C3 treatment. The average value of total nitrogen was between 0.28-1.31 g·kg\(^{-1}\), and the total nitrogen content of 0-10 cm soil layer was significantly higher than that of 10-20 cm and 20-30 cm soil layer. In the 0-10 cm soil layer, the total nitrogen content of C3 treatment was significantly higher than other treatments, and the compound ratio and soil layer had significant effects on total nitrogen. The average value of C/N was between 1.72-5.92, which was the lowest at 0-10 cm, and the value decreased with the increase of the volume fraction of soft rock, and the treatment with C3 was the most significant. When the ratio of soft rock to sand was 1:1, it can promote the accumulation of carbon and nitrogen in the surface soil of 0-10 cm and enhance the decomposition of microorganisms.

1. Introduction

Soil organic carbon is a class of compounds with specific structure and high molecular weight, which has obvious response to changes in different agricultural production measures and environmental factors [1]. As one of the three major plant nutrients, nitrogen has a certain coupling relationship with
soil organic carbon. The carbon to nitrogen ratio (C/N) can reflect the stability and effectiveness of soil nutrients, and can be used as an important indicator to characterize soil fertility [2]. Therefore, the study of C/N in soft rock and sand can provide a theoretical reference for farmland conservation and management and selection of planting patterns.

At present, domestic and foreign scholars have reported on the study of organic carbon and total nitrogen in natural geomorphology. According to Wang et al. [3] studied on soil organic carbon and nitrogen succession in yellow paddy fields developed from limestone and sand shale, soil organic carbon and total nitrogen basically showed a linear growth trend with the increase of fertilization years, and C/N was basically stable around 12.3. Hyvonen et al. [4] studied the carbon stability and nitrogen storage of 15 observatories in northern Europe, pointing out that the increased of nitrogen input can reduce the mineralization loss of organic carbon and indirectly promoted the storage and accumulation of organic carbon. The direct input pathway of organic carbon such as organic fertilizer can promote the accumulation and maintenance of nitrogen to a certain extent. It can be seen that carbon and nitrogen were interdependent and have a certain coupling relationship. Zhang et al. [5] studied the carbon to nitrogen ratio of forest soils, and showed that the C/N range of different typical forests ranged from 9.27 to 28.23, and there was a significant positive correlation between soil carbon and nitrogen content. The soft rock and sand are two kinds of “harmful” resources widely distributed in the Mu Us sandy Land. At present, the research on the soft rock and sand compound soil of the team members mainly exists in the physical and chemical structure and water retention performance [6]. There are few studies on the nutrient cycling and characterization system of compound soil, and the relationship between C/N and nutrient elements has not been involved yet. Therefore, this paper takes the soil with different proportion of soft rock and sand as the research object, mainly studies the C/N of the soil with different soil layers, and the results can provide scientific basis for the evaluation of the quality of the composite soil and the improvement of soil fertility.

2. Materials and methods

2.1. Overview of the study area
Fuping County (108°57′-109°26′E, 34°42′-35°06′N) is the transition zone between the Guanzhong plain and the northern Shaanxi plateau, and belongs to the gully region of the Weihe Loess Plateau. The elevation in the territory is 375.8-1420.7 m. The area belongs to the continental monsoon warm zone with semi-arid climate. The annual total radiation is 5187.4 MJ m$^{-2}$, the annual average sunshine hours is about 2389.6 h, the annual average temperature is 13.1 °C, and the annual average precipitation is 527.2 mm.

2.2. Experiment design
The field test plot was to simulate the land condition of the soft rock and sand mixed layer in the Mu Us sandy Land. The experimental plot was to lay a mixture of soft rock and sand at 0-30 cm, and fill the aeolian sandy soil with 30-70 cm. The soft rock and sand were taken from Daji Han Village, Xiaoji Han township, Yuyang district, Yulin city. The test was carried out in 2016, and four treatments of soft rock and sand in a volume ratio of 0:1 (CK), 1:5 (C1), 1:2 (C2), and 1:1 (C3) were selected. Each treatment was repeated 3 times for a total of 12 trial plots. The area of the plot was 2 m×2 m = 4 m$^2$. The experimental field was corn (Jincheng 508)-wheat (Xiaoyan 22), which was made by two crops a year, all of which were artificially sown. The types of fertilizers tested in the experimental field were urea (including N 46.4%), diammonium phosphate (including N 16%, containing P$_2$O$_5$ 44%), potassium sulfate (including K$_2$O 52%), and the amount of fertilizer applied was 255 kg hm$^{-2}$(N), 180 kg hm$^{-2}$(P$_2$O$_5$) and 90 kg hm$^{-2}$(K$_2$O).

2.3. Soil sample collection
After the wheat harvest in May 2018, samples of 0-30 cm soil layer in each plot (10 cm interval) were collected, and each plot was uniformly collected 5 points to form a mixed sample. The collected soil
samples were used to remove animal and plant residues. The soil sample was naturally dried air milled 0.149 mm sieve for the determination of organic carbon, total nitrogen.

2.4. Determination method
Soil organic carbon was determined by potassium dichromate-concentrated sulfuric acid external heating method, total nitrogen was measured using an elemental analyzer (EA3000, Ovette, Italy) [7].

2.5. Data processing and analysis
All data were classified and charted by EXCEL 2019, SPSS 19.0 was used for ANOVA and multiple comparisons.

3. Results and discussion

3.1. Compound soil organic carbon content
The soil organic carbon contents of 0-10 cm, 10-20 cm and 20-30 cm soil layers were between 2.07-2.65 g·kg⁻¹, 1.45-2.70 g·kg⁻¹ and 1.49-2.03 g·kg⁻¹, respectively. The average content gradually decreased with the deepening of the soil layer, and the organic carbon content of 0-10 cm soil layer was significantly higher than that of 20-30 cm soil layer (Fig. 1). In the 0-10 cm soil layer and the 20-30 cm soil layer, there was no significant difference in the organic carbon content under all compounding treatments (P>0.05). In the 10-20 cm soil layer, the organic carbon content of CK treatment was significantly higher than that of other compounding ratios (P<0.05), and there was no significant difference among other treatments. The content of organic carbon treated with CK was the highest in all treatments, which was 2.03-2.70 g·kg⁻¹, and the highest organic carbon content was obtained in CK treatment with 10-20 cm soil layer, followed by 0-10 cm and 20-30 cm minimum. With the increase of the proportion of soft rock, the organic carbon content in 10-20 cm soil layer decreased in turn, and the highest organic carbon content in 0-10 cm soil layer was C3 treatment. C2 treatment had the highest organic carbon content in 20-30 cm soil layer. It is indicated that with the increase of the content of soft rock, the soil organic carbon content in each soil layer was redistributed, which promotes the accumulation of organic carbon in the surface soil of 0-10 cm. Further analysis of variance showed that (Table 1), the compounding ratio treatment had a significant effect on the organic carbon content, while the soil layer had no significant effect, while the combined effect of the two was not obvious.

![Figure 1](image-url). The vertical distribution characteristics of soil organic carbon and total nitrogen under different compound ratios of soft rock and sand.
Table 1. The variance analysis table for each determination index under the influence of two factors.

| Index             | Influencing factor       | Quadratic sum | Free degree | Mean square | F value | P value |
|-------------------|--------------------------|---------------|-------------|-------------|---------|---------|
| Organic carbon    | Compound ratio           | 2.5994        | 3           | 0.8665      | 3.919   | 0.0207  |
|                   | Soil layer               | 1.2635        | 2           | 0.6317      | 2.857   | 0.0771  |
|                   | Compound ratio × Soil layer | 1.1151      | 6           | 0.1859      | 0.841   | 0.5511  |
| Total nitrogen    | Compound ratio           | 0.9265        | 3           | 0.3088      | 34.221  | 0.0001  |
|                   | Soil layer               | 1.3922        | 2           | 0.6961      | 77.128  | 0.0001  |
|                   | Compound ratio × Soil layer | 0.2679      | 6           | 0.0446      | 4.947   | 0.002   |
| C/N               | Compound ratio           | 43.0899       | 3           | 14.3633     | 14.006  | 0.0001  |
|                   | Soil layer               | 19.8871       | 2           | 9.9435      | 9.696   | 0.0008  |
|                   | Compound ratio × Soil layer | 7.1677      | 6           | 1.1946      | 1.165   | 0.3573  |

3.2. Compound soil total nitrogen content

The total nitrogen content in the 0-10 cm, 10-20 cm and 20-30 cm soil layers was within the range of 0.70-1.31 g·kg⁻¹, 0.37-0.70 g·kg⁻¹ and 0.28-0.63 g·kg⁻¹ under different mixing ratios of soft rock and sand (Fig. 1). The average content gradually decreased with the deepening of the soil layer, and the total nitrogen content in the 0-10 cm soil layer was significantly higher than that in the 10-20 cm and 20-30 cm soil layer (P<0.05). In the 0-10 cm soil layer and the 10-20 cm soil layer, the total nitrogen content of C3 treatment was significantly higher than other treatments, but there was no significant difference between the other treatments (P>0.05). In the 20-30 cm soil layer, the difference of C2 and C3 treatment was not obvious, and the total nitrogen content was significantly higher than that of C1 and CK treatment. There was no significant difference between C1 treatment and CK treatment. The average total nitrogen content of C3 treatment was the highest in all treatments, and the total nitrogen content of CK, C1 and C3 treatments showed a tendency to decrease with the deepening of soil layers, while the C2 treatment showed 20-30 cm soil layers. The nitrogen content is higher than the 10-20 cm soil layer. Further analysis of variance showed that (Table 1), the compounding ratio treatment and different soil layers had a significant effect on the total nitrogen content (P<0.01), and the combined effects of the two also had significant effects.

3.3. Compound soil carbon to nitrogen ratio (C/N)

The range of C/N in the 0-10 cm, 10-20 cm and 20-30 cm soil layers under different proportions of soft rock and sand was 1.72-3.80, 2.05-5.92 and 2.96-5.62, respectively (Fig. 2). The average C/N was 10-20 cm, the highest was 20-30 cm, and the lowest was 0-10 cm. In each soil layer, the C/N treated by CK was the largest, ranging from 3.80 to 5.92, and its value decreases with the increase of the content of soft rock. The C/N treated by CK, C1 and C2 had no significant difference under the 0-20 cm soil layer, but the C/N of CK treatment was significantly higher than that of C3 treatment in the 0-10 cm soil layer, in the 10-20 cm soil layer. The C/N of CK, C1 and C2 treatments were significantly higher than C3 treatment. In the 20-30 cm soil layer, there was no significant difference in C/N treated by C1 compared with CK, and the C/N treated by CK and C1 was significantly higher than that treated by C2 and C3, while there was no significant difference between C2 and C3. Further analysis of variance showed that (Table 1), the compound ratio treatment and different soil layers had a significant effect on C/N (P<0.01), while the combined effect of the two was not significant.
4. Conclusion
With the increase of the soft rock content, the soil organic carbon and total nitrogen content in each soil layer were redistributed, which promoted the accumulation of soil organic carbon and total nitrogen in 0-10 cm surface soil. The compounding ratio treatment and different soil layers had significant effects on C/N (P<0.01), while the combined effects of the two were not significant. When the ratio of soft rock to sand is 1:1, it can promote the accumulation of carbon and nitrogen in the surface soil of 0-10 cm and enhance the decomposition of microorganisms.

Acknowledgments
This study is financially supported by The Shaanxi Provincial Land Engineering Construction Group internal research project (DJNY2019-12, DJNY2018-12), Fund Project of Shaanxi Key Laboratory of Land Consolidation (2018-JC18, 2019-JC07), Changan University Central University Basic Research Business Expenses Funding Project (300102279503).

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