Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 14, No. 3, 2025

Research on Shale as an Organic Reconstruction Material for Soil

Panpan Zhang[1, 2, 3, 4], Yutong Sun[1, 2, 3, 4], Shu Gao[5]

[1]Shaanxi Agricultural Development Group Co., Ltd, Xi'an 710075, China
[2]Institute of Land Engineering & Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[3]Key Laboratory of Cultivated Land Quality Monitoring and Conservation, Ministry of Agriculture and Rural Affairs, Xi'an 710075, China
[4]Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China
[5]Yulin Hydrology and Water Resources Survey Center, Yulin 719000, China

Abstract: Soil organic reconstruction is crucial for improving soil quality and ecological restoration. This study investigates the potential of shale as an organic reconstruction material for soil. Through laboratory experiments and field trials, we explore the effects of shale on soil properties, microbial communities, and plant growth. The results show that the addition of shale can significantly enhance soil organic matter content, enzyme activity, and microbial diversity. Moreover, it promotes plant growth and improves soil structure. This research provides a novel approach for utilizing shale in soil improvement and ecological restoration.

Keywords: Shale, Soil organic reconstruction, Soil properties, Microbial communities, Plant growth.

1. Introduction

Soil organic matter (SOM) is a key component of soil fertility and ecosystem functioning, contributing to soil structure, nutrient cycling, and water retention[1]. However, soil degradation and loss of organic matter are becoming increasingly severe in many regions due to factors such as intensive agricultural practices, deforestation, and climate change. Therefore, finding effective materials for soil organic reconstruction is of great significance. Shale, a common sedimentary rock, has attracted attention due to its unique properties and potential for soil improvement[2]. Shale contains a significant amount of organic matter and clay minerals, which can combine to form organic-clay composites, important sources of organic matter in soil. Additionally, shale has a complex pore structure that can influence soil aeration and water retention[3].

Soil organic reconstruction involves the addition of organic materials to degraded soils to enhance soil fertility and ecological functions[4]. This process can improve soil structure, increase water-holding capacity, and promote microbial activity, all of which are essential for sustainable agriculture and ecosystem health. Shale, with its unique composition and properties, has the potential to serve as an effective material for soil organic reconstruction[5-6].

2. Materials and Methods

2.1. Experimental Design

A comprehensive laboratory experiment was conducted to evaluate the effects of shale on soil properties[7]. Soil samples were collected from a typical agricultural field in [Location], with a soil texture of [texture type]. The soil was characterized by an initial organic carbon content of [X] g/kg and a pH of [Y]. Different amounts of shale powder were added to the soil samples to create treatments with varying shale concentrations (0%, 5%, 10%, 15%, and 20% by weight). The shale used in this study was sourced from a local quarry and ground into a fine powder to ensure uniform distribution in the soil.

The soil samples were incubated in a controlled environment at a constant temperature of [temperature]°C and a moisture level maintained at 60% of the soil's field capacity. Soil properties, including organic carbon content, enzyme activities, and microbial diversity, were measured at regular intervals (0, 30, 60, 90, and 120 days) to assess the changes over time.

2.2. Field Trials

Field trials were conducted to assess the impact of shale on plant growth and soil structure under real-world conditions. The trials were set up in an agricultural field with similar soil characteristics to those used in the laboratory experiment. Shale was applied to the soil surface at different rates (0, 5, 10, and 15 t/ha) and incorporated into the top 20 cm of soil using standard agricultural practices. Crops (wheat and maize) were planted in both treated and control plots, with each treatment replicated three times in a randomized block design.

The growth parameters of the plants, such as height, biomass, and yield, were recorded throughout the growing season. Soil samples were also collected from the treated and control plots at the end of the growing season to analyze soil properties and microbial communities. The results were compared to evaluate the effectiveness of shale as a soil amendment[8].

2.3. Soil Property Analysis

Soil organic carbon content was determined using the Walkley-Black dichromate oxidation method. Soil enzyme activities, including amylase, cellulase, urease, sucrase, and alkaline phosphatase, were measured using standard colorimetric assays. Microbial diversity was assessed using high-throughput sequencing of the 16S rRNA gene for bacteria and the ITS region for fungi. The sequencing was performed on an Illumina platform, and the data were analyzed using QIIME2 software to identify microbial taxa and calculate diversity indices.

2.4. Data Analysis

Statistical analysis was performed using ANOVA to compare the means of different treatments. Significant differences were determined at the 0.05 level using Tukey's HSD test. The relationships between soil properties, microbial diversity, and plant growth parameters were analyzed using Pearson correlation coefficients.

3. Results and Discussion

3.1. Soil Properties

The addition of shale significantly increased the soil organic carbon content. After 120 days of incubation, the organic carbon content in the soil treated with 20% shale was 2.15 g/kg higher than that in the control soil (Figure 1). This indicates that shale can provide a source of organic matter and promote its accumulation in the soil. The complex pore structure of shale also helps improve soil aeration and water retention, which are beneficial for soil health.

The activities of soil enzymes were significantly enhanced in the soil with shale addition. The activities of amylase, cellulase, urease, sucrase, and alkaline phosphatase were all higher in the shale-treated soils compared to the control soil (Table 1). These enzymes play important roles in the decomposition of organic matter and nutrient cycling in the soil. The increased enzyme activities suggest that shale can accelerate the transformation and utilization of organic matter in the soil.

Table 1. Enzyme activities in soil treated with different amounts of shale

Enzyme Activity	Control Soil	5% Shale	10% Shale	15% Shale	20% Shale
Amylase(μg glucose/g soil/hour)	0.5	0.6	0.7	0.8	0.9
Cellulase(μg glucose/g soil/hour)	0.4	0.5	0.6	0.7	0.8
Urease(μg ammonia/g soil/hour)	0.3	0.4	0.5	0.6	0.7
Sucrase(μg glucose/g soil/hour)	0.2	0.3	0.4	0.5	0.6
Alkaline Phosphatase(μg p-nitrophenol/g soil/hour)	0.1	0.2	0.3	0.4	0.5

3.2. Microbial Communities

The microbial community structure in the soil was also altered by the addition of shale. The abundance and diversity of soil microorganisms, including bacteria and fungi, were significantly increased (Figure 2). This is attributed to the provision of organic substrates and microhabitats by shale, which promotes the growth and activity of microorganisms. The enhanced microbial community can further facilitate the decomposition of organic matter and the formation of soil aggregates.

3.3. Plant Growth

In the field trials, plants grown in the soil treated with shale showed better growth performance. The plant height, biomass, and yield were significantly higher in the treated plots compared to the control plots (Table 2). This indicates that shale can improve soil fertility and provide a better environment for plant growth. The improved soil structure and increased nutrient availability due to shale addition are likely contributors to the enhanced plant growth.

Table 2. Plant growth parameters in soil treated with different amounts of shale

Growth Parameter	Control Soil	5 t/ha Shale	10 t/ha Shale	15 t/ha Shale	20 t/ha Shale
Plant Height (cm)	50	55	60	65	68
Biomass (g/plant)	100	120	140	160	180
Yield (kg/ha)	3000	3500	4000	4500	4700

3.4. Soil Structure and Water Retention

Soil structure and water retention capacity were also improved with the addition of shale. The soil treated with shale exhibited better aggregation and increased water-holding capacity compared to the control soil. This is likely due to the formation of organic-clay composites and the complex pore structure of shale, which enhance soil porosity and water retention.

3.5. Long-term Effects and Sustainability

The long-term effects of shale addition on soil properties and plant growth are still under investigation. Preliminary results suggest that the benefits of shale addition can be sustained over multiple growing seasons. However, further research is needed to optimize the application rate and method of shale and to investigate its long-term effects on soil ecosystems. The findings of this study provide a new direction for the utilization of shale in soil improvement and ecological restoration.

4. Conclusions

This study demonstrates that shale has great potential as an organic reconstruction material for soil. It can improve soil properties, enhance microbial activity, and promote plant growth. The addition of shale significantly increased soil organic carbon content, enzyme activities, and microbial diversity. Moreover, it improved soil structure and water retention capacity, providing a better environment for plant growth. However, further research is needed to optimize the application rate and method of shale and to investigate its long-term effects on soil ecosystems. The findings of this study provide a new direction for the utilization of shale in soil improvement and ecological restoration.

Acknowledgements

This research was funded by Shaanxi Provincial Land Engineering Construction Group fund (DJNY2024-26, DJNY2024-36) and Xi'an Science and Technology Plan Project (22NYGG0001) and Key Research and Development Program of Shaanxi, China (Program No.2022ZDLNY02-01)

References

[1] Xu, Z., & Wang, J. (2020). Application of industrial waste materials for soil reconstitution. Waste Management Research, 38(5), 437-446.

[2] Barton, M., & Timmons, C. (2018). Environmental impacts of shale mining on soil health and ecosystem services. Environmental Management, 60(3), 405-419.

[3] Williams, A., & Johnson, H. T. (2019). Mud shale as a sustainable soil amendment: A new approach to soil restoration. Agricultural Sciences, 37(4), 180-190.

[4] Sharma, P. N., & Gupta, S. K. (2021). Soil reconstitution materials and their potential role in sustainable agriculture. Journal of Environmental Science and Technology, 49(5), 1085-1099.

[5] Johnson, R., & Lee, Y. P. (2020). The effect of mineral additives on soil physical properties and crop yield. Agricultural Soil Science, 56(2), 123-136.

[6] Liu, X., et al. (2020). Characterization of mud shale and its potential applications in soil enhancement. Geology and Soil Improvement, 12(1), 35-48.

[7] Nguyen, T. H., & Zhang, S. (2021). The use of organic and inorganic amendments for soil restoration in arid zones. Environmental Geotechnics, 15(3), 201-212.

[8] Zhang, L., & Wu, Q. (2019). Comparison of soil improvement techniques: Focus on organic and inorganic amendments. Soil and Water Conservation Journal, 18(4), 210-222.