Design of the Mix Ratio for TRD Construction Waste as a Growing Medium

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Abstract: To investigate the feasibility of using TRD construction waste as a planting substrate for ecological restoration, this study conducted indoor pot experiments to compare the effects of mixed substrates comprising TRD construction waste and ordinary soil in varying proportions on the growth characteristics of tall fescue. The study measured and analysed the growth dynamics of plant height and changes in growth density over different cultivation periods, thereby identifying the suitability of TRD construction waste for use as a planting substrate and determining the optimal blending ratios. The results indicate that when the proportion of TRD spoil does not exceed 25%, the growth rate and density of tall fescue reach levels comparable to those achieved when grown in pure ordinary soil. However, when the proportion exceeds this threshold, the growth of tall fescue is significantly inhibited, with plant height growth slowing and growth density decreasing. This indicates that, following appropriate blending, TRD spoil can be utilised as a raw material for planting substrates in ecological restoration, thereby enabling the on-site ecological utilisation of construction waste soil.

Keywords: Construction waste; Red soil; Vegetation trials; Resource recovery

1. Introduction

The TRD (Trench Cutting Re-mixing Deep Wall) method is widely used in projects such as waterproof curtain walls for deep excavations, retaining structures, embankment waterproofing and the isolation of contaminated sites [1]. However, this method generates waste slurry during construction, the main components of which are natural soil, weathered rock fragments, concrete debris, brick and stone particles, and other solid construction waste [2], constituting typical construction waste. With the continuous expansion of urban construction in China, the volume of TRD spoil is growing exponentially, with annual production nationwide now exceeding 119 million tonnes; however, the actual resource recovery rate remains below 1% [3], and research into the resource utilisation of excavated soil and spoil remains relatively limited. Current primary treatment methods include direct reuse [4], simple treatment [5], soil improvement techniques [6], high-temperature sintering technology [7], or the use of construction waste for landscaping to meet urban greening soil requirements [8]. Wang Feng et al. [9] investigated the effects of different improvement and substitution methods on the physicochemical properties of construction waste soil; the results showed that the physicochemical indicators of the improved soil met the requirements of the 'Soil for Greening and Planting' standard. This paper aims to explore the optimal mixing ratio of TRD waste soil and ordinary red soil for crop cultivation.

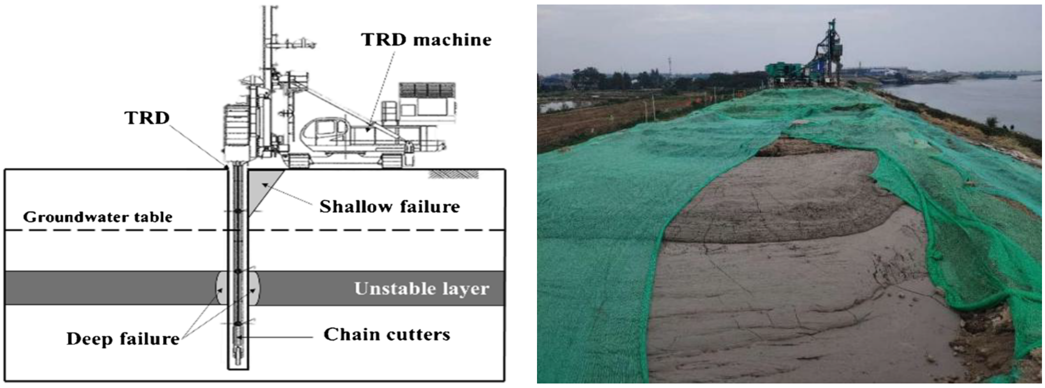

Figure 1: TRD Construction and the Generation of Excavated Soil.

2. Test Methods and Materials

2.1 Test Materials

2.1.1 TRD spoil

The TRD spoil was extracted from the plastic concrete impermeable wall and channel-cut cement-treated soil (TRD) projects, which form part of the seepage control measures for the embankment body and foundation in the key embankment reinforcement works in the Dongting Lake area of Hunan Province. The project is expected to generate 3.2 million tonnes of spoil, which is primarily formed by the hardening of a mixture of undisturbed soil, cement, bentonite and admixtures. On-site sampling and analysis revealed that the newly produced TRD spoil has a high moisture content and high fluidity, appearing dark grey in colour. After standing for a period, it consolidates into blocks with a dense texture, as shown in Figure 2. Its main chemical composition is presented in Table 1, with the primary constituents being SiO2 (51.42%), CaO (19.28%) and Fe2O3 (6.25%), exhibiting typical characteristics of construction spoil. After retrieval, the newly produced slag was placed in a dry, well-ventilated area to air-dry naturally. It was then manually crushed and sieved, with particles of the appropriate size selected as test samples.

Figure 2: TRD Spoil.

Table 1: Chemical Composition of TRD Spoil.

SiO_2(%)	Al_2O_3(%)	Fe_2O_3(%)	CaO(%)	MgO(%)	K_2O(%)	Na_2O(%)	TiO_2	P_2O_5
51.41	14.58	6.85	19.28	1.99	3.05	0.32	0.96	0.21

2.1.2 Ordinary Soil

By way of comparison, the control soil was collected from a flower bed in Building 8 on the campus of Hunan Agricultural University, in an area that had not been significantly disturbed by human activity; the soil type in this area is typical red soil and is therefore highly representative. During collection, five points were selected uniformly within the designated area using the five-point sampling method. Topsoil (0–20 cm) was collected from each point. The collected soil was mixed thoroughly, then crushed and sieved to select soil particles of suitable particle size as test samples, ensuring the consistency of the test material properties. The soil is shown in Figure 3. The chemical composition of the ordinary soil is shown in Table 2. The main constituents are SiO2 (66.45%), Al2O3 (17.99%) and Fe2O3 (6.25%). Compared with TRD waste soil, the ordinary soil has a higher SiO2 content, whilst the CaO content is significantly lower than that of TRD waste soil; this is partly due to the presence of hydration products from cement mortar in the composition of the TRD waste soil.

Figure 3: Ordinary Soil.

Table 2: Chemical Composition of Ordinary Soil.

SiO_2(%)	Al_2O_3(%)	Fe_2O_3(%)	CaO(%)	MgO(%)	K_2O(%)	Na_2O(%)	TiO_2	P_2O_5
66.45	17.99	6.25	1.55	1.83	3.68	0.43	0.99	0.29

Table 3: Other Raw Materials.

Name	Model	Retailer
Caesar tall fescue seed	Gold Standard	Suqian Dijing Landscape Gardening Engineering Co., Ltd.
Organic potting compost	General-purpose	Hunan Tuzhongtuba Agricultural Technology Co., Ltd.
Compound fertiliser	Instant	Shandong Kleno Biotechnology Co., Ltd.
Premium Green Zeolite	2mm-3mm	Huaduoduo Fresh Flower Gardening Co., Ltd.

2.2 Test Method

The sun-dried TRD spoil was crushed and sieved to obtain particles smaller than 2 mm, which were then mixed with ordinary soil samples in ratios of 0%, 25%, 50%, 75% and 100%. The experimental groups are shown in Table 4. Growth trials were conducted using tall fescue as the test species. The plants were planted in mixed substrates containing different proportions of TRD spoil and ordinary soil, and their growth was observed and recorded to identify the optimal mixture ratio.

Through the aforementioned experimental design, the ecological effects of TRD spoil were comprehensively assessed, along with its impact on the germination rate, germination time and early growth of slope protection plants, thereby identifying the optimal mixture ratio of TRD spoil for plant growth.

Table 4: Trial Grouping Table.

Category	TRD soil	Ordinary soil
T1	0	100%
T2	25%	75%
T3	50%	50%
T4	75%	25%
T5	100%	0%

The plant growth box measures 10 cm × 20 cm × 15 cm. Using a hand drill, drill five evenly spaced drainage holes with a diameter of 2 mm in the base of the box. First, place two eco-concrete blocks, each measuring 100 mm × 100 mm × 100 mm, inside the box to form the base layer. Next, fill the box with the growing medium prepared according to the experimental mix ratio, ensuring it covers the concrete blocks and maintains a thickness of at least 4 cm. Sow the pre-treated seeds evenly over the surface of the substrate. Finally, cover with a 1 cm layer of substrate to form a shallow mulch, and water lightly. Keep the top 1 cm of soil moist until germination. Place the container indoors until germination, then move it to a shaded area outdoors. Once germinated, water thoroughly once every morning. See Figure 4 for the planting process.

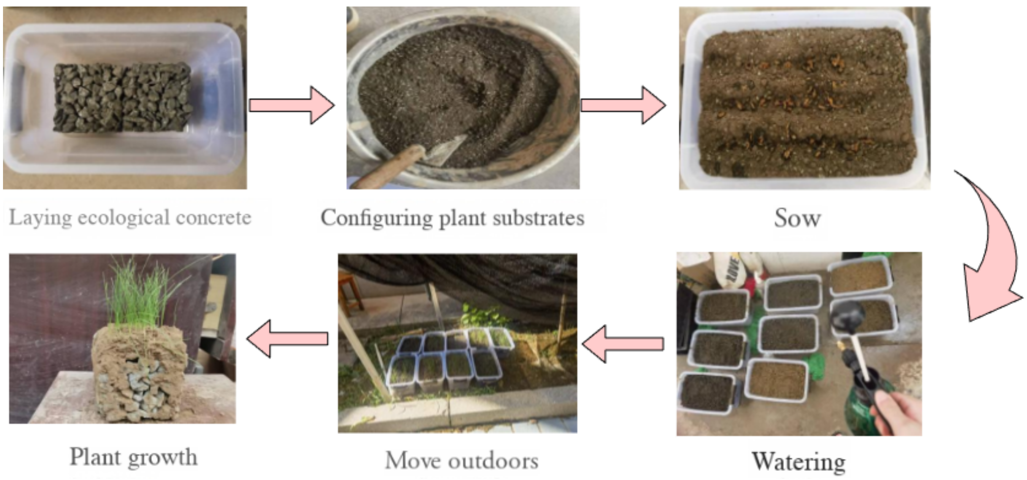

Figure 4: Planting Tall Fescue.

3. Results and Discussion

3.1 Test Results

3.1.1Tall Fescue with a High Growth Curve

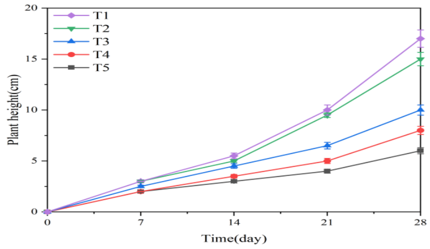

Figure 5: Growth Curve of Tall Fescue Plant Height.

As shown in Figure 5, the growth trends in tall fescue plant height varied across the different treatment groups over time. During the first seven days of the pot experiment, there were minimal differences in plant height between the treatment groups; however, as time progressed, these differences gradually became apparent. In Group T1, due to suitable soil conditions, tall fescue growth was relatively stable, with plant height continuing to increase; in Group T2, the addition of a small amount of construction waste did not significantly inhibit plant growth, and the trend in plant height was similar to that of Group T1; in Group T3, as the proportion of construction waste increased, the rate of tall fescue plant height growth slowed somewhat, yet growth continued to a certain extent; in Group T4, the growth of tall fescue was further restricted, with growth rates significantly slower than in the preceding groups; in Group T5, due to issues such as excessively high soil pH and low organic matter content, tall fescue growth was severely inhibited, with plant height increasing extremely slowly; in some periods, growth even stagnated or showed negative growth.

3.1.2 Tall Fescue Growth Density Curve

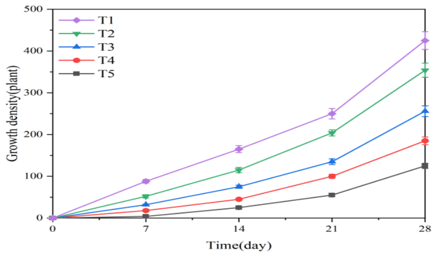

Figure 6: Growth Density Curve for Tall Fescue.

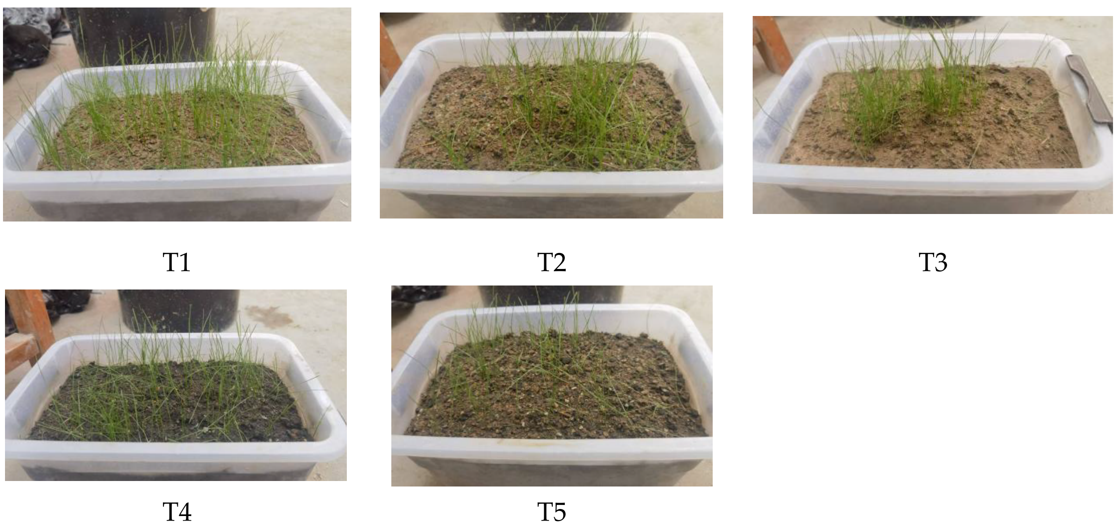

Figure 7: Tall fescue growth density (28 days).

The experimental results indicate that the growth density of tall fescue in the different treatment groups exhibited varying trends over time. During the early stages of cultivation (the first seven days), there were no significant differences in growth density among the treatment groups, and the plants were distributed relatively evenly. However, as time progressed, differences gradually became apparent. In Group T1, due to favourable soil conditions, the tall fescue grew rapidly, with growth density increasing continuously, resulting in a relatively dense stand; In Group T2, the addition of a small amount of construction waste did not affect the growth density of tall fescue; its growth density was similar to that of Group T1 and remained at a high level; in Group T3, as the proportion of construction waste increased, the rate of growth density increase slowed somewhat, but the plants were still able to arrange themselves relatively closely, forming a certain degree of vegetation cover; In Group T4, the growth density of tall fescue was somewhat restricted, with increased gaps between plants and a corresponding reduction in coverage; in Group T5, due to unfavourable factors such as excessively high soil pH and low organic matter content, the growth of tall fescue was severely inhibited, resulting in extremely low growth density and an inability to form effective vegetation cover.

3.2 Discussion of the Experiment

A comparison of the tall fescue plant height curves across the treatment groups clearly shows that, as the proportion of TRD-treated soil increases, the growth of tall fescue is inhibited to varying degrees; however, mixing with ordinary soil can alleviate this inhibitory effect to some extent, thereby promoting plant growth. In particular, the plant height in the T2 group was notably high, coming very close to that of the T1 group and reaching 92% of the T1 group's level.

A comparison of the tall fescue growth density curves across the treatment groups clearly reveals that, as the proportion of TRD waste soil increases, the growth density of tall fescue is inhibited to varying degrees; however, the treatment in Group T2 utilised the properties of the waste soil whilst mitigating its adverse effects on plant growth, resulting in a growth density very close to that of the pure ordinary soil treatment group, reaching 89% of the latter's level.

4. Conclusion

This study conducted growth trials on tall fescue using different mixtures of TRD construction waste and ordinary soil, with the aim of identifying the optimal soil mixture for tall fescue growth. A comprehensive analysis of the observed results for plant height and growth density reveals that:

(1) When TRD waste soil is blended into ordinary soil in varying proportions, the growth of tall fescue is progressively inhibited as the proportion of waste soil increases; however, mixtures containing low proportions of waste soil do not have a significant negative impact on the growth of tall fescue.

(2) In this experiment, under the T2 treatment (25% TRD spoil), both the plant height and growth density of tall fescue were close to those observed when grown in pure ordinary soil. This mitigated the adverse effects of the physicochemical properties of TRD spoil on plant growth, making it the optimal soil mixture ratio for tall fescue growth in this trial.

(3) This mixture ratio provides a reference for the resource utilisation of TRD spoil in engineering vegetation restoration. Further trials could be conducted for different plant species and under varying soil amendment conditions to expand the application scenarios of TRD spoil

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