

Study on the Effect of the Copper Tailing Substrate with Different Treatments on the Growth of Tall Fescue (*Festuca arundinacea* Schreb)

Jinchun Xue

JiangXi University of Science and Technology

Weiwei Wang

JiangXi University of Science and Technology

MIN HE (✉ 2792412235@qq.com)

JiangXi University of Science and Technology <https://orcid.org/0000-0001-7452-5035>

Jiajia You

JiangXi University of Science and Technology

Huaqin Han

JiangXi University of Science and Technology

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Abstract

The copper sulphide mining process would produce a large number of copper tailings that can be treated with different substrates so as to act as guest soil in the ecological reclamation of the mine. Tall fescue (*Festuca arundinacea Schreb*) is a fast-growing herbal medicinal plant with a large biomass and significant adaptability that is often used as pioneer plant in early mining soil reclamation. In order to reveal the influence of different copper tailing treatment substrates on plant growth, in this experiment, tall fescue (*Festuca arundinacea Schreb*) was planted under potted conditions for the purpose of exploring the effect of different exogenous substrates such as conditioning agents, sulfurized modified straw, effective microorganisms (EM), and High-density Sludge (HDS) sediment on tall fescue height, biomass, chlorophyll, catalase (CAT) activity and Cu^{2+} transport under copper tailings substrate. Then, the results showed that the combined application of different exogenous substrates (conditioning agents, EM, sulfurized modified straw and HDS sediment) reduced the pH of the copper tailing substrate to varying degrees, with a decrease of 5%-21%. Besides, compared with the control group and other treatments, the combined treatment of conditioning agents, sulfurized modified straw, and EM has a significant impact on the biomass, plant height, chlorophyll content, CAT activity and other physiological indicators of tall fescue and can effectively reduce Cu^{2+} that is toxic to tall fescue in copper tail sand.

1 Introduction

With the rapid development of society and economy, the demand for copper resources is increasing. However, the mining of copper resources will inevitably cause a large number of copper tailing discharge problems. According to statistics, the output of tailings in China alone was about 1.211 billion tons, of which the annual output of copper tailings was about 302 million tons in 2018. Whereas, the utilization rate of copper tailings was less than 10% (Guo et al. 2014). Copper tailings piled up in quantity not only caused serious waste and imbalance of land resources, but resulted in serious pollution and harm to the ecological environment. To be specific, first of all, copper tailings contain a huge number of pollutants such as heavy metals and beneficiation agents that will pass physical, chemical, and biological migration into the atmosphere, water bodies, and soil, thus causing environmental pollution. Apart from that, dust and fine sand will negatively affect the environment of the surrounding areas, and sandstorms often occur in arid and windy areas (Ms et al. 2014; R et al. 2006). Secondly, the large accumulation of copper tailings leads to land degradation, desertification, and salinization, thus arousing a series of ecological problems such as the destruction of vegetation and even threatening the safety of humans and animals in the mining area (Lam et al. 2017; Maric et al. 2013). Other than that, the copper tailings occupy a large amount of agricultural and forest land, causing the land resources in the area to be out of balance (Rodrigo et al. 2021). In addition, the unsafe hidden dangers caused by the continuous accumulation of copper tailings are also increasing. Especially when a large amount of rainwater enters, the rainwater runoff may form a landslide. If rainwater is improperly intercepted and discharged in the dump, it is easy to induce landslides, mudslides and other geological disasters in the case of rainstorms and flood infiltration (Wang et al. 2017). Therefore, the rational utilization of copper tailing resources is imperative.

Considering copper tailings are featured with poor structure, extremely poor nutrients, and high content of heavy metals, there are few plants that can grow naturally there, which restricts its restoration and management to a great extent (Valentín-Vargas et al. 2014; Kumar et al. 2008). Vegetation reconstruction is the most effective and economic way, which includes the use of appropriate organic or inorganic added and the selection of appropriate plant species (Guo et al. 2014). Therefore, determining the plant species is essential to ensure sustainable vegetation cover. Fischer et al. suggested plant tolerance to heavy metal is the result of natural selection rather than innate physiological inheritance (Fischer et al. 2017). In recent studies, tall fescue shows high tolerance as well as enrichment ability to various heavy metals, including Cd, Cu, Pb and Zn (Zhu et al. 2020). Lou et al. pointed out that compared with most herbal plants, tall fescue demonstrates excellent growth potential under saline-alkali and high-temperature environments, with great advantages in saline-alkali tolerance and drought resistance and they usually grow well in soils with pH of 4.7 to 9.0. Furthermore, tall fescue can normally live on heavy metal contaminated soil and uptake of a certain quantities of heavy metal (Lou et al. 2017). Lan et al. and Ye et al. have investigated reclamation of lead-zinc mines in southern China by applying tolerant plants (e.g., *Cynodo dactydon*) and organic additives (e.g., manure and garbage compost) and achieved success (Lan et al. 1998; Ye et al. 1999). Besides, the research conducted by G. Fellet et al. showed that adding biochar to the tailings can enhance the substrate's nutrition and water retention properties and reduce the bioavailability of certain pollutants. The use of biochar in mine wastes helps plants build the green covering layer in the process of plant stabilization (Fellet et al. 2011). In addition, Asha A. Juwarkar et al. added ETP sludge, biological fertilizer and mycorrhizal fungi to the planting substrate, which increased the organic matter of the substrate while reducing the toxicity of heavy metals and provided better anchorage and growth of the selected plants on the coal gangue pile. The support material (Juwarkar et al. 2008). The available concentration of plants helps promote the initial restoration of vegetation in the contaminated soil of wasteland (Walker et al. 2004). Apart from that, GP Kumar and others used different organic modifiers such as biological sludge, dairy sludge, and biological fertilizers to conduct greenhouse experiments on plant substrates. Appropriate measures provide nutrients for plant growth and reduce the metal toxicity of plants while supporting plant growth, thereby promoting the growth of *Jatropha curcas* (*Jatropha curcas* L.) (Kumar et al. 2008). At present, there are many studies on the improvement of contaminated soil in mining areas and the screening of tolerant plants. However, Single material has limited effectiveness and the cost is high. The growth status of higher plants was used for detection of pollution degree in soil, which was one of the most important approaches to measure soil health and evaluate soil quality from an ecological perspective (Hernández-Apaolaza et al. 2020). Considering that, in this paper, the perennial herbaceous tall fescue (*Festuca arundinacea* Schreb) is taken as the research object. Besides, an 8-week outdoor pot experiment is performed to explore the effect of different treatments concerning exogenous substrates such as conditioning agents, sulfurized modified straw, EM and HDS sediment on tall fescue in copper tailings. Then, physical and chemical indicators such as plant height, biomass, chlorophyll content, CAT enzyme activity, Cu^{2+} transport coefficients of the surviving plants were analyzed and discussed in order to screen out the effect for improving plant growth.

2 Materials And Methods

2.1 Materials

2.1.1 Plants Materials

The fresh samples of seeds of tall fescue (*Festuca arundinacea Schreb*) used in the study were obtained commercially from Muyangdou Seed Research Industry Co., LTD. The plant was identified and authenticated in the Herbarium, Biology Department, Nanjing University, with voucher number 19103042.

2.1.2 Other Materials

Test copper tailings: copper tailings of the copper mine were collected from the 4# tailing reservoir of Dexing Copper Mine in Jiangxi Province, using the grid point method, and sampled with a small shovel at each sampling point for collecting tailings of 0–20 cm surface layer samples, used for the pot experiment. As for copper tailings, the particle size is extremely small, while the bulk density is 1.6g cm⁻³, and the pH value is between 8.5-9.0. Besides, the conditioning agent was made by mixing peat soil, medical stone, calcite, frankincense, oil cake, and compound fertilizer in proportion. Here, it should be mentioned that the pH value of the tested HDS sediment is between 7.5-9.0. In addition, the phosphorus and potassium required for plant growth in the HDS sediment are within the normal range, while the nitrogen content is very small. Furthermore, the tested EM is a microbial inoculum composed of more than 80 species of 10 genera, mainly photosynthetic bacteria, lactic acid bacteria, yeasts and actinomycetes. After drying, the test straw was cut into 5-8cm sections and modified with 10% ammonium sulfate solution.

2.2 Experimental design and treatments

There were five experimental groups in the experiment, denoted as CK, T1, T2, T3 and T4, and 3 parallel groups for each group. In detail, in CK group, only 1500 g pure tailings were added; T1 group was 1600 g pure tailings + 60 g conditioning agents; T2 group was 1500 g pure tailings + 60 g conditioning agents + 250 g EM + 10 g sulfurized modified straw; T3 group was 1500 g pure tailing sand + 60 g conditioning agents + 250 g EM; the T4 group is 1000 g pure tailings + 500 g HDS sediment + 60 g conditioning agents + 10 g sulfurized modified straw + 250 g EM. Then, chose the flower pots with a diameter of 235 mm, sow 20 reed-shaped tall fescue seeds in each pot featured with the depth of 2 cm, and compacted them by hand. After that, water the seeds less than once three days before emergence to avoid lowering the temperature and apply the same amount of water every two days after emergence. In the first week after sowing, the number of seed germination was recorded, and the growth height of the plant was recorded once every two weeks. After 8 weeks, samples were taken for analysis.

2.3 Plant Analysis and Statistical Analysis

The biomass and morphology tests were performed in quintuplicate, and the remaining tests were performed in triplicate. Ten tall fescue seedlings were randomly taken out from the five pots of the

respective treatment group and then rinsed with tap water twice to prevent residual copper tailings from causing errors in the test results. Afterward, the fresh samples were placed in an electric heating blast drying box (DHG-2200B, Zhengzhou Shengyuan instrument Co. LTD) at 105°C for 30 min and then kept at 80°C for 6h. Then, the dry weight was measured. Beyond that, the ethanol extraction method was adopted to measure the content of chlorophyll a, chlorophyll b in this study (Li et al. 2022), while Catalase activity was determined using UV spectrophotometry (Guo et al. 2020), and the Cu^{2+} content was determined using inductively coupled plasma atomic emission spectroscopy (Tan and Yu et al. 2019). Furthermore, the pH value of the substrate was determined by the water extraction potential method (the ratio of water to soil was 2.5:1) (Zheng et al. 2021). SPSS 20 software was adopted for the one-way analysis of variance (ANOVA), and statistical differences between treatments were conducted by performing Duncan's multiple range test ($P < 0.05$), Microsoft Excel 2016 and Origin 9.1 software were employed for drawing.

3 Results

3.1 Influence of different exogenous substrates on the pH value of copper tailings

It can be seen from Table 1 that the original copper tailings are alkaline, and the pH of each substrate dealt with different treatments is significantly different ($P < 0.05$), considering they are all between 7 and 8.55. When a conditioning agent is added to the copper tailings (T1 treatment), the pH of the copper tailings drops by 0.39 units. When conditioning agent and EM (T3 treatment) are added to the copper tailings, the pH of the copper tailings experiences a significant drop. It becomes neutral, which is related to the acidity of the EM and conditioning agent itself. Compared with T3 treatment, T2 treatment had a smaller drop in pH of copper tailings by 1.38 units, while compared with the T2 treatment, the pH decrease of the copper tailing substrate was even smaller. Although there was no significant difference in the pH of the copper tailing substrate accepting the T1, T3, T2, and T4 treatments after planting tall fescue for 2 months ($P > 0.05$), each treatment did not cause a fundamental change in the pH of the substrate. However, for the copper dealt with different treatments, the pH of the tailing sand substrate was higher than that of the copper tailing sand without planting tall fescue, which reflected that the copper tailing sand experiencing different treatments planted with tall fescue tended to be alkaline.

Table 1

The effect of planting tall fescue on the pH value of copper tailings with different exogenous substrates

Treatment	CK	T1	T2	T3	T4
pH of unplanted tall fescue substrate	8.83 ± 0.04 ^a	8.44 ± 0.07 ^b	7.45 ± 0.05 ^d	7.01 ± 0.01 ^e	7.77 ± 0.03 ^c
Substrate pH after planting tall fescue for 2 months	9.29 ± 0.04 ^a	8.49 ± 0.13 ^b	7.95 ± 0.12 ^c	8.52 ± 0.20 ^b	7.99 ± 0.03 ^c

Note: The data in the above table are average values ± standard deviations. The same line of letters in the table indicates no significant difference between the treatments with different substrate pH values. The different letters refer to a significant difference between the treatments with different substrate pH values ($P < 0.05$). CK Group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.

3.2 Effects of different exogenous substrates on the biomass and plant height of tall fescue

It can be shown from Fig. 1 that the tall fescue treated with CK withered, turned yellow, grew short and had low coverage, which was typical characteristics of malnutrition and heavy metal poisoning. On the contrary, the tall fescue treated with conditioners, microorganisms, sulfurized modified straw and bottom mud grew well. Compared with the CK group, the growth status of tall fescue was improved after the copper tailing matrix was added with a conditioning agent (T1 treatment), while in comparison with the T3 treatment, in the T1 treated copper tailing matrix after the addition of microbial inoculants, the reed, the coverage and growth of fescue have not been improved. After covering the surface of the copper tailing matrix with the conditioning agent and EM with a layer of sulfurized modified straw (T2 treatment), the tall fescue grew luxuriantly. Moreover, when T4 was compared with T2, the survival rate and coverage of tall fescue decreased significantly after the addition of HDS sediment, indicating that HDS sediment is not suitable as an exogenous additive substrate for the green reclamation of copper tailings.

Plant biomass and height can directly reflect plant growth and development. Figure 2 shows the effect of different exogenous substrates on the biomass of tall fescue, while Fig. 3 displays the effect of different exogenous substrates on the height of tall fescue.

It can be seen from Fig. 2 that after 8 weeks of tall fescue growth, the biomass of the CK group was the lowest compared with that of other treatment groups, with a value of 0.24 g, and the combination of different exogenous substrates increased its biomass to varying degrees. Apart from that, the effect of T2 treatment was the most obvious, and its biomass increase was 3.75 times that of the CK group, reaching a significant difference level ($P < 0.05$). In contrast, T1, T3, and T4 treatments had similar effects on tall fescue biomass. Among these 3 species, there was no significant difference between the two treatments of tall fescue biomass ($P > 0.05$), and the increase was 1.96 times, 2.00 times, and 1.88 times that of the

CK group respectively, demonstrating that the combined application treatment (T2 treatment) can better improve the growth environment of tall fescue on the copper tailing sand substrate and promote the growth of tall fescue.

For the same plant, the higher the plant height, the greater the coverage, while the better the prevention of wind erosion and water erosion of tailings, the better the return of organic matter after plant death. The plant height changes of plants growing on different substrates during the same growth period can reflect the adaptability of plants to the substrate. Furthermore, it can be seen from Fig. 2 that due to the lack of nutrients required for plant growth in the CK group, plant growth was inhibited, and the plant height increased slightly. Besides, the tall fescue did not change from the 2nd week to the 8th week, while T1, in the copper tailing sand substrate treated with T2 and T4, the plant height of tall fescue increased in different degree. Compared with T1 and T4, the plant height of tall fescue after T2 treatment increased significantly, while compared with the CK group, the height of tall fescue after T3 treatment decreased, which reflects that tall fescue is more adaptable to the growth environment of the copper tailing substrate treated with conditioning agents, EM, and sulfurized modified straw (T2 treatment).

3.3 Effects of different exogenous substrates on the content of chlorophyll and CAT activity in tall fescue

Figure 4 and Fig. 5 respectively present the effect of different exogenous substrates on the chlorophyll and the CAT activity of tall fescue.

It can be known from Fig. 4 that the combined application of different exogenous substrates has different degrees of influence on the chlorophyll content of tall fescue. There are significant differences in the chlorophyll content of tall fescue between T2 and T4 treatments and the CK group. The increase in the chlorophyll content of tall fescue is the most obvious, with an increase of 141% and 150%, respectively. In terms of the treatment groups T1, T3 and CK, there was no significant difference between the two groups. The chlorophyll content of tall fescue increased by 81% and 40%, respectively. Compared with the CK group, the increase of chlorophyll b in the T1 to T4 treatment groups was 46%, 99%, 18% and 106% accordingly, and there was no significant difference in the chlorophyll b content of tall fescue among the copper tailing sands treated with different treatments.

From Fig. 5, it can be found that the combination of different exogenous substrates effectively increased CAT activity. Compared with the control group CK, the treatment groups T1, T2, T3, and T4 increased by 230%, 287%, 487%, and 528%, respectively. Whereas, the difference between treatments was significant ($P < 0.05$). Under the copper tailing matrix, when the treatment group T1 was compared with the control group CK, the single application of the conditioning agent could significantly increase the CAT activity, and when the treatment group T3 was compared with T1, the addition of EM could increase the CAT activity of the conditioning agent alone. When T2 and T3 were compared, as well as T4 and T2, the effect of treatment group T2 and T3, T4 and T2 were not significant. The addition of sulfurized modified straw improved the effect of treatment group T3 to a great extent, while the addition of HDS sediment failed to largely increase CAT activity in treatment group T3.

3.4 Effects of different exogenous substrates on Cu²⁺ transport in tall fescue

Transport coefficients are generally used to analyze the ability of plants to transport heavy metals above the ground, which is of great significance to the removal of heavy metals from the soil. As shown in Fig. 6, the copper content of the underground and above-ground parts of the CK group was 590.12 mg/kg and 34.04 mg/kg, respectively, while that of the underground parts of the plants in the T1, T2, T3, and T4 groups decreased compared with the control group. Regarding copper content in the above-ground parts of plants, the T1 group increased by 20.0% compared with the CK group, whereas the T2, T3, and T4 groups decreased by 41.6%, 3.9% and 75.1% separately, compared with the CK group. Moreover, the Cu content of tall fescue grown in copper tailing substrates with different exogenous substrates is quite different. To be specific, the Cu content of the above-ground part of the tall fescue in each treatment of the copper tailing sand matrix is T1 > CK > T3 > T2 > T4, while that of the underground part is CK > T1 > T3 > T4 > T2, which may be due to the effect of microorganisms on dissolved Cu. It has a strong complexing ability, and the porous surface of sulfurized modified straw possesses a certain adsorption capacity for Cu. Therefore, the Cu content of tall fescue under the substrate of copper tailings treated with T2, T3, and T4 is significantly lower than that in the ground and underground. Control group CK. Under different treatments, the transport coefficients of tall fescue in the copper tailing substrate were all less than 1. In addition, the difference was not significant, meaning that the tall fescue was mainly enriched in the underground part of Cu.

4 Discussion

The measurement results concerning main physiological indexes of tall fescue under different copper tailing substrate treatments showed that the pH, biomass, plant height, chlorophyll, CAT activity and Cu²⁺ transport coefficient of tall fescue undertake various influence of different exogenous substrates, such as conditioning agents, EM, sulfurized modified straw and HDS sediment.

The pH of copper tailings is its most basic physical and chemical property. It interacts with the activities of microorganisms in copper tailings, the synthesis and decomposition of organic matter, the transformation, release and effectiveness of various nutrients, and the ability of copper tailings to retain nutrients. Relationship (Tang et al. 2020). Other than that, it has an important influence on the element ions that plant roots absorb minerals. Furthermore, the pH of the copper tailing matrix decreased to different degrees after the application of different exogenous substrates. On the one hand, the pH of the conditioning agent and EM was 5.0–6.0. In addition, adding sulfurized modified straw could enhance the exchangeability of copper tailings, whereas the content of calcium, exchangeable magnesium, and exchangeable potassium increases the base saturation of the copper tailings (Wang et al. 2020). Therefore, the pH of the copper tailing matrix treated with T2 is higher than that with T3. Apart from that, the copper tailing matrix treated with T4 may result from the sediment containing a large amount of Ca²⁺. When the Ca²⁺ in the sediment starts to become saturated, the external Na⁺ infiltrates into the soil along

with rainfall, resulting in a balance of charges in the sediment. Besides that, the sediment colloid has a strong adsorption capacity for Na^+ , which leads to the release of Ca^{2+} , which is even higher than the pH of the copper tailing matrix treated with T2 (Tuteia & Mahajan. 2007). According to observations, the tall fescue planted on copper tailings is short, with withered stems and leaves, mainly due to the poor nutrients of the copper tailing matrix, low water holding capacity, and lack of key soil microbial diversity, which is not conducive to the normal growth of plants (Machado et al. 2013; R et al. 2014). As for the growth of tall fescue, it was obviously different after different exogenous substrates were treated with copper tailings. Among them, the combined application of conditioning agents, EM and sulfurized modified straw (T2 treatment) could further promote the growth of tall fescue. It is a conditioning agent that provides nutrients for the microorganisms in the copper tailing matrix to improve the biological fertility of the copper tailing matrix and enhance the structure of the copper tailings matrix (Hamid et al. 2018; Wang et al 2020). On the other hand, sulfurized modified straw strengthens the water retention of the copper tailings. In addition to that, performance and hyphae appear on the contact surface between sulfurized modified straw and the copper tailings, thus improving the living environment of microorganisms, and further effectively enhancing the plant suitability of the copper tailings and the suitable environment for the growth of tall fescue. Moreover, the change of chlorophyll content is an adaptive change of plants to adversity conditions (Sharma & Kaur 2020). Compared with the copper tailing substrates treated with different treatments, the chlorophyll content of tall fescue grown on the original copper tailings is lower, maybe because various heavy metal elements in the copper tailing substrate are absorbed and transported to the leaf parts through the roots, forming the plant body. Whereas, the chlorophyll structure is destroyed, and the synthesis of chlorophyll is hindered, which leads to a decrease in the chlorophyll content of plants. Firstly, adding the conditioning agent, EM, and HDS sediment can dilute the heavy metals in the copper tailings (Zhang & Cao 2020; Malar et al. 2016). Secondly, the sulfurized modified straw rebuilds an uncontaminated surface layer on the copper tailings, which effectively alleviates the stress of heavy metals on plants and promotes plant growth (Zhou et al. 2016; Arsenov et al. 2021; Zamulina et al. 2021). In this case, it is indicated that the lower the content of chlorophyll, the stronger the stress of plants, and the weaker the adaptability and tolerance of plants to copper tailing substrates. Different exogenous substrates can appropriately improve the copper tailing substrate to increase plant chlorophyll content and light. Cooperative efficiency. CAT is universally present in plant tissues, and its activity is related to the metabolic strength of plants and the ability of cold resistance and disease resistance. In the process of plant growth and development, its activity is constantly changing. Therefore, CAT activity can be taken as a reference physiological indicator of plant resistance (Zhang et al. 2018; Na et al. 2018). Compared with the control group, the CAT activity of tall fescue was significantly increased after the copper tailing sand substrate was treated with different treatments, possibly because different treatments improved the growth environment of tall fescue and promoted the growth of tall fescue, whereas the metabolism of plants is strong, and the production of free radicals increases. In order to maintain the normal growth of plants to the utmost extent, the plant will induce the synthesis of more CAT to eliminate the large number of free radicals produced to ensure the normal growth of plants (Huang et al. 2019; Chen et al. 2017). Therefore, the treatment of different copper tailing sand substrates alleviated the stress of the copper tailing sand substrate on the tall fescue

and improved the resistance of the tall fescue to the copper tailing sand substrate. The Cu content of tall fescue in the control group is higher than that in other groups, which may be due to the strong complexing ability of EM to dissolved Cu, while the loose and porous surface of sulfurized modified straw has a certain adsorption capacity for Cu, and the coverage of HDS sediment rebuilds an uncontaminated surface layer for the copper tailings matrix, causing the Cu in the copper tailings to be adsorbed and deposited in HDS sediment by the porous particles when it migrates to the plant roots, effectively reducing the tall fescue Right Cu absorption (Ji et al. 2018; Wang et al. 2020; Reis et al. 2020).

5 Conclusions

With the rapid development of society and economy, the demand for copper resources is increasing. However, the contradiction between mining activities and the environment has become more prominent, which has caused a serious impact on the sustainable development of economy. Therefore, effective land reclamation and ecological reconstruction in mining areas are crucial for achieving sustainable economic, social and ecological development. In this context, exogenous substrates are used to process the copper tailings so as to enhance the physical and chemical properties of the copper tailings that can even replace the shallow soil and become the plant growth substrate for the ecological restoration of the mine. In a word, the above methods can improve the utilization rate of copper tailing resources, solve vegetation stripping, soil erosion, river blockage, debris flow, land desertification and other environmental damage caused by copper tailing stacking, and provide experience for the future environmental management of other mines to some extent.

Declarations

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Conflicts of interest/Competing interests

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

Availability of data and material

All data included in this study are available upon request by contact with the corresponding author.

Code availability

Not applicable.

Authors' contributions

Weiwei Wang performed the data analyses and wrote the manuscript;

Jinchun Xue and contributed to the conception of the study;

Jiajia You contributed significantly to analysis;

Min He performed the experiment;

Huaqin Han helped perform the analysis with constructive discussions;

Ethics approval

Experimental research and field studies on plants complies with relevant institutional, national, and international guidelines and legislation.

Consent to participate.

Not applicable' for that section.

Consent for publication

Not applicable' for that section.

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Figures

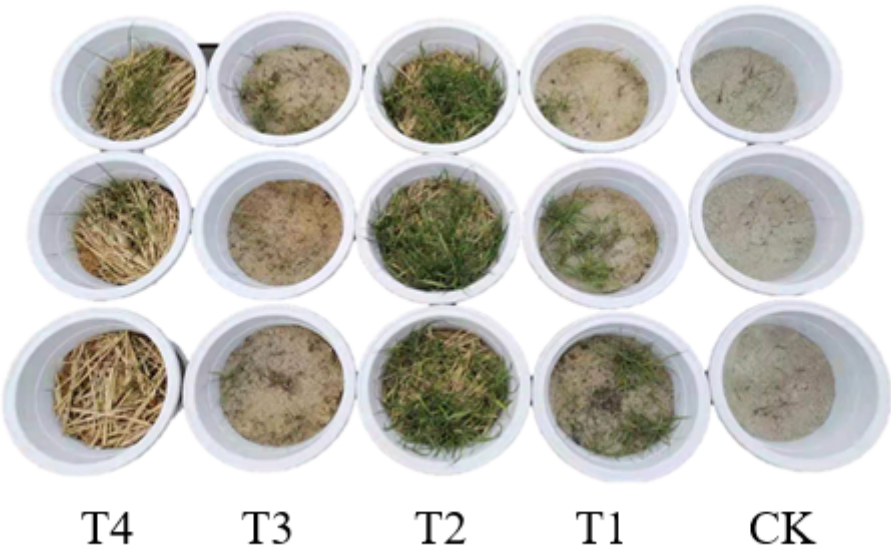


Figure 1

The effect of different exogenous substrates on the growth of tall fescue; CK group is 1500 g pure tailings; T1 group is 1500 g pure tailings + 60 g conditioning agents; T2 group is 1500 g pure tailings + 60g conditioning agents + 250 g EM+ 10 g sulfurized modified straw; T3 group is 1500 g pure tailings + 60 g conditioning agents + 250 g EM; T4 group is 1000 g pure tailings + 500 g conditioning agents + 60 g sulfurized modified straw + 250 g EM + 10 g HDS sediment.

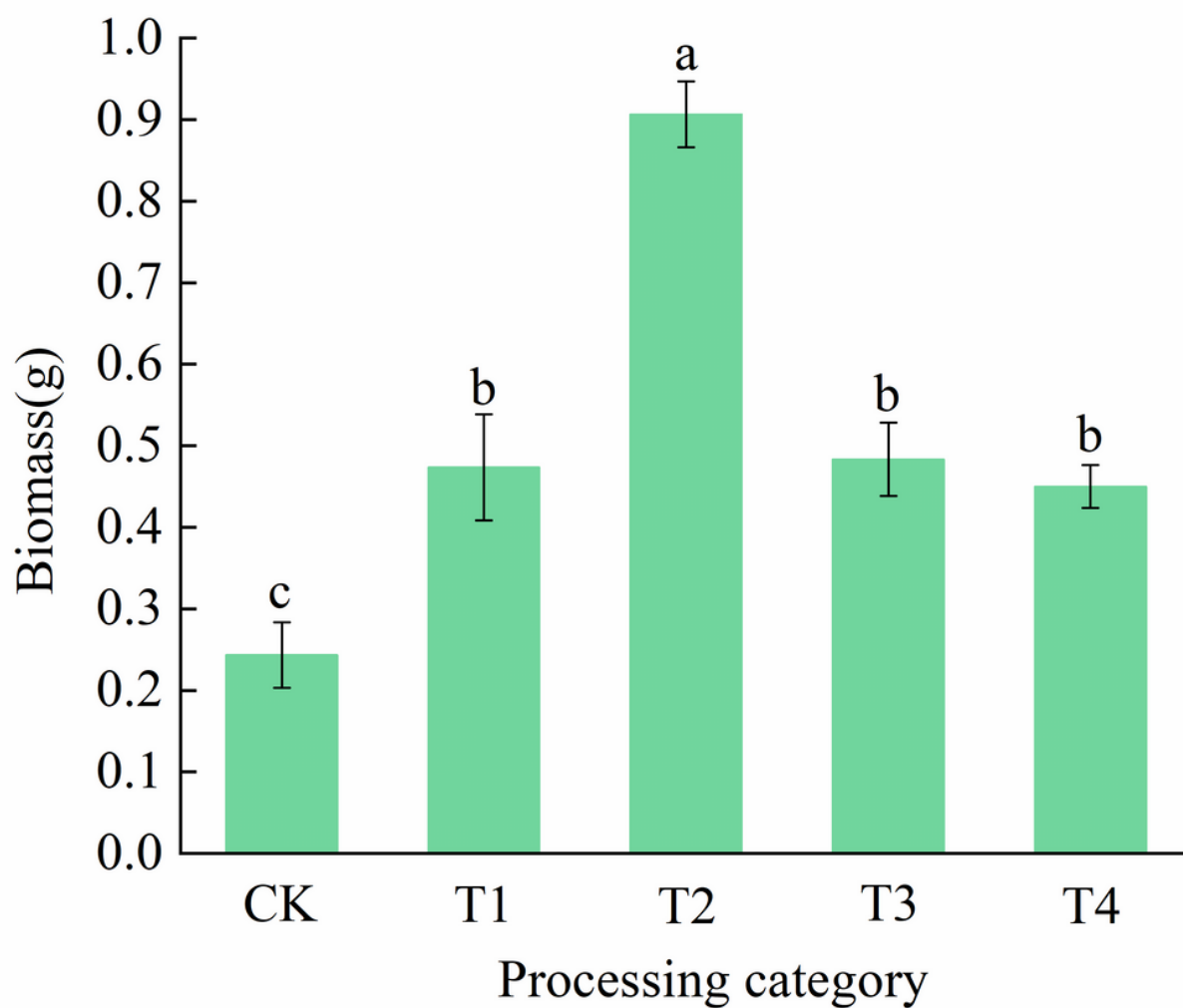


Figure 2

The effect of different exogenous substrates on the biomass of tall fescue; samples with the same letters are not significantly different according to the Tukey-Kramer honestly significant difference test ($\alpha = 0.05$). CK group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.

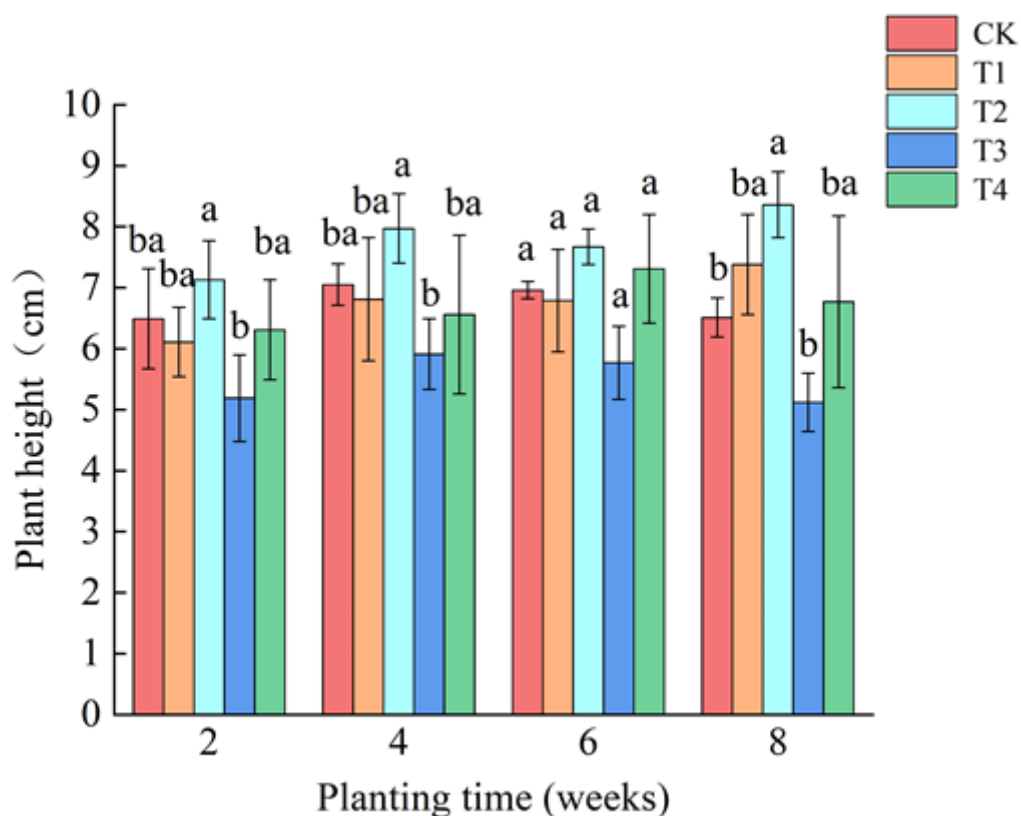


Figure 3

The effect of different exogenous substrates on the height of tall fescue; samples with the same letters are not significantly different according to the Tukey-Kramer honestly significant difference test ($\alpha = 0.05$). CK group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.

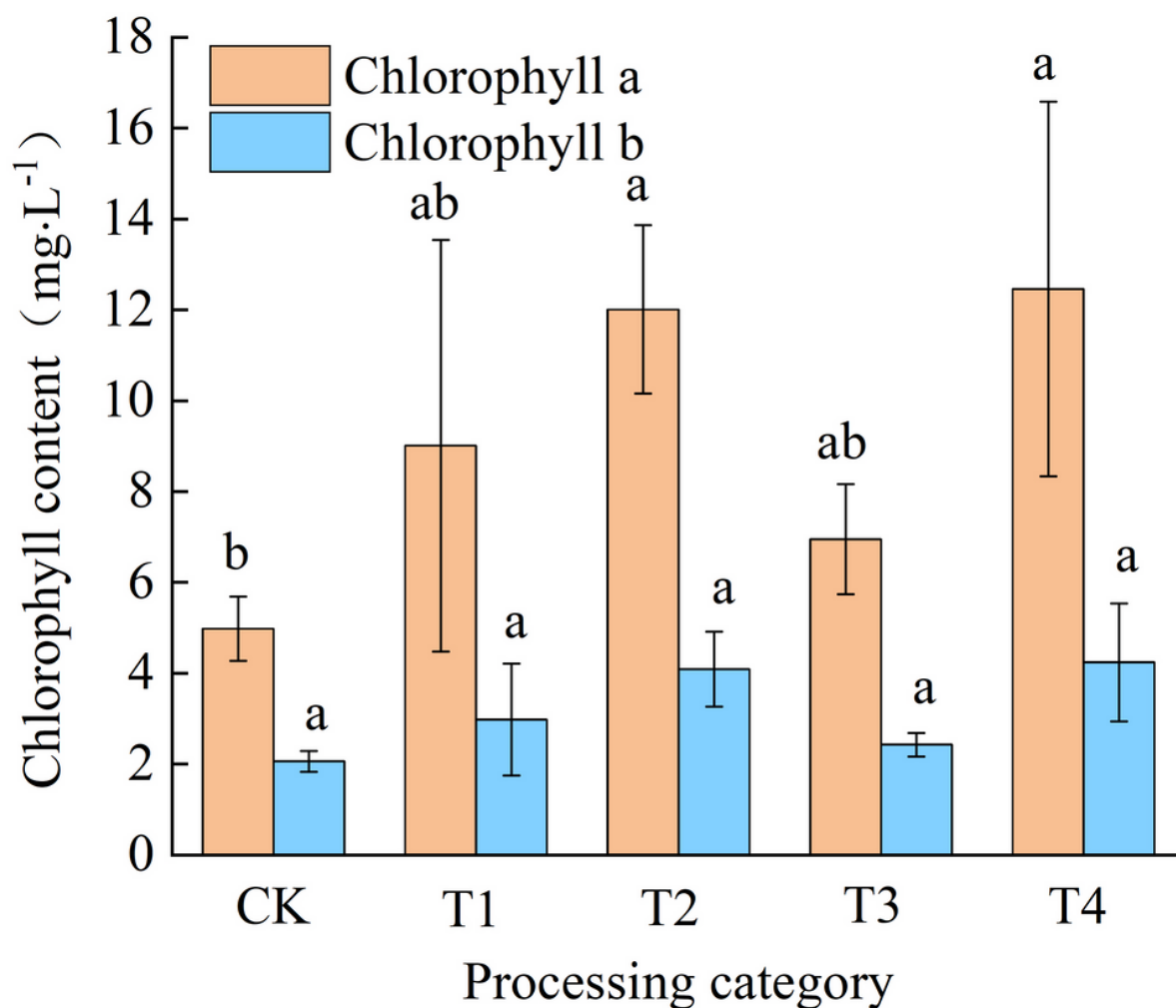


Figure 4

The effect of different exogenous substrates on the chlorophyll of tall fescue; samples with the same letters are not significantly different according to the Tukey-Kramer honestly significant difference test ($\alpha = 0.05$). CK group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.

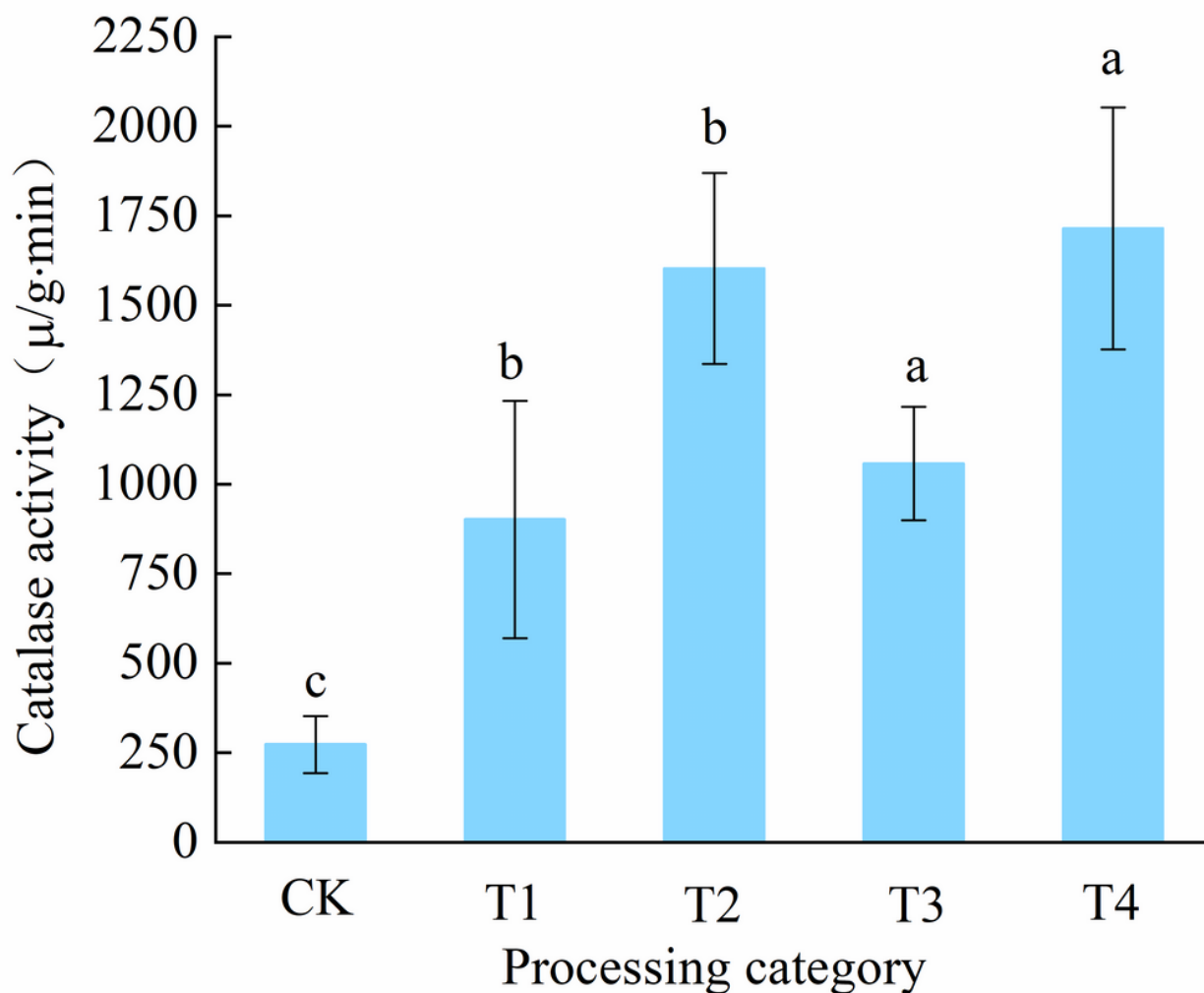


Figure 5

The effect of different exogenous substrates on the catalase activity of tall fescue; samples with the same letters are not significantly different according to the Tukey-Kramer honestly significant difference test ($\alpha = 0.05$). CK group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.

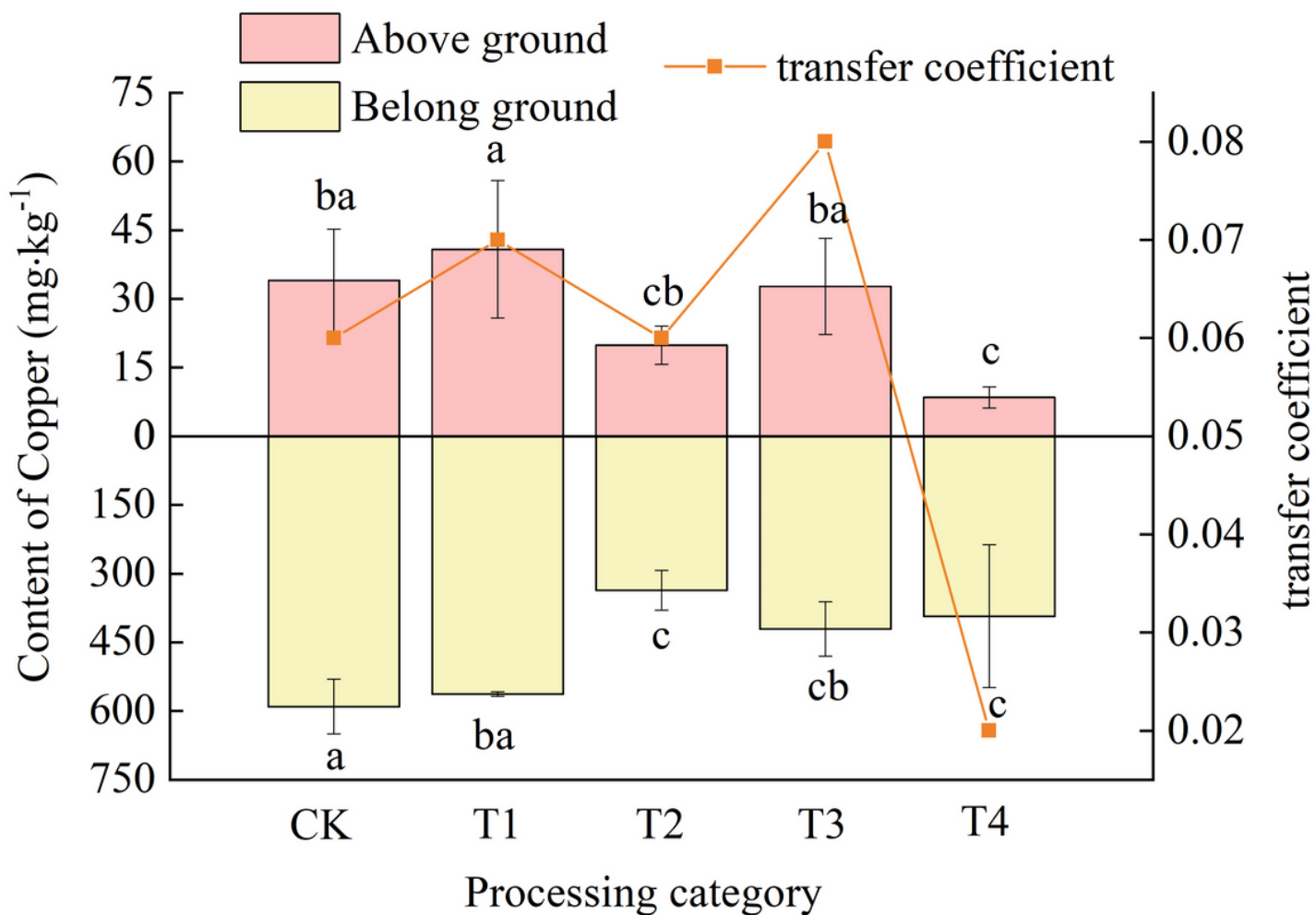


Figure 6

The effect of different exogenous substrates on the Cu transport coefficient of tall fescue; samples with the same letters are not significantly different according to the Tukey-Kramer honestly significant difference test ($\alpha = 0.05$). CK group is pure tailings; T1 group is pure tailings + conditioning agents; T2 group is pure tailings + conditioning agents + EM + sulfurized modified straw; T3 group is pure tailings + conditioning agents + EM; T4 group is pure tailings + conditioning agents + sulfurized modified straw + EM + HDS sediment.