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Influence of Different Types of Organic Fertilizer on Tea Quality and Soil Nutrients

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ABSTRACT The application of organic fertilizer is an important practice for enhancing tea quality. It plays a vital role in improving the physical and chemical properties of the soil, regulating the soil environment, and promoting the production of high-quality tea. This study evaluated the effects of six different fertilization treatments on tea quality and soil nutrients in tea gardens. The treatments included local conventional fertilization (T1) and five types of oil-dry organic fertilizers (T2, T3, T4, T5, and T6). The results showed that, compared to conventional fertilization (T1), tea leaves under T3 and T6 treatments exhibited the highest quality. Additionally, T2, T3, and T6 significantly improved the physical and chemical properties of the soil. These treatments effectively reduced soil acidification while enhancing the overall quality of the tea garden soil. Among the treatments, T3 demonstrated the most favorable results. It promoted tea tree growth, improved soil fertility, and significantly enhanced tea quality. This highlights the potential of organic fertilizers in addressing soil degradation and boosting tea production. These findings provide valuable insights into sustainable tea cultivation practices. The study establishes a reference for improving tea quality and optimizing soil management in tea gardens

Keywords: *Organic; Fertilizer; Tea; Nutrient; Traits; Soil*

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INTRODUCTION Tea tree is one of the important economic crops in China and occupies an important position in the agricultural economy (Yang et al., 2019). As the main tea producing area in China, Yunnan province takes the lead in tea garden area, and its output and output value also rank among the best in China, ranking the third and the 5th respectively. The physical and chemical characteristics and nutrient content of tea garden soil have a decisive influence on the strong growth of tea trees and the quality of tea leaves (Tian et al., 2022). However, if the fertilization method is improper, it will not only lead to the decline of tea yield and quality, but also cause serious pollution to the ecological environment, thus hindering the sustainable and healthy development of the tea industry (Yan et al., 2022, Chang et al., 2022). Compared with chemical fertilizer, the application of organic fertilizer in tea garden can significantly improve the content of water extract, tea polyphenols, catechin and other important components in tea; at the same time. The application of organic fertilizer can significantly affect the yield of tea, nitrogen, phosphorus and potassium in tea and the accumulation of soil fertility (Zeng et al., 2024, Saeed et al., 2024, Rashid et al., 2024).

Building on the critical role of tea cultivation in China's agricultural economy, particularly in Yunnan Province, the adoption of sustainable fertilization practices has become increasingly important. Yunnan, with its vast tea garden areas and significant contribution to national tea output, faces challenges such as soil degradation and declining tea quality due to improper fertilization methods. These challenges underscore the need for alternative strategies to balance productivity with ecological sustainability. Among these strategies, the use of organic and biological fertilizers has gained attention for their potential to address soil health issues while enhancing tea quality and yield (Yan et al., 2022).

Organic fertilizers not only enrich the soil with essential nutrients but also improve soil structure, water retention, and aeration, which are critical for the robust growth of tea trees. Biological organic fertilizers, in particular, go a step further by incorporating beneficial microorganisms that enhance nutrient availability, suppress soil-borne diseases, and promote root development. This study seeks to evaluate the effects of various organic fertilizers on tea quality and soil nutrients in Yunlong County, offering valuable insights into practical approaches for sustainable tea production. By understanding these impacts, researchers and farmers can develop methods to increase tea production efficiency while preserving the long-term fertility of tea garden soils (Tian et al., 2022).

Biological organic fertilizer can effectively improve the soil compaction caused by the application of chemical fertilizer. It is a new, efficient and safe fertilizer with the effect of both microbial fertilizer and organic fertilizer. Biological organic fertilizer improves the rhizosphere microbiome of crops, improves the disease resistance of plants, and was applied in the soil improvement of tea garden (Chen et al., 2024). The application of biological organic fertilizer can improve the soil environment, increase the number of soil microorganisms, and play an important role in maintaining the activity and ecological stability of microorganisms, but also promote the increase of crop production by (Zhan et al., 2024). Biological organic fertilizer, to a certain extent, can reduce the soil compaction, promote the root development of tea trees, provide a better growth environment for tea trees, and finally play a good effect of increasing production, quality and efficiency of tea (Yan et al., 2024).

Through the field tests of different kinds of organic fertilizers implemented in Baofeng Township of Yunlong County, the specific effects of these organic fertilizers on tea quality and soil nutrient composition are deeply understood and analyzed, aiming to provide scientific and effective theoretical basis and practical guidance for improving the quality and yield of tea in Yunlong County

MATERIAL AND METHODS

Overview of the experimental site

The experimental site is located in Dalishu Village, Baofeng Township, Yunlong County, Dali Bai Autonomous Prefecture, Yunnan Province. It is located in the low latitude plateau, mainly with the low latitude plateau monsoon climate. The annual average temperature of the village is 19°C. The annual frost-free period is 251 days, the flat rainfall is 800mm, the relative humidity is 70%, and the sunshine duration is 1700h.The basic physicochemical properties of the soil in the test area are pH 4.60, organic matter content 86.1g/kg, hydrolytic nitrogen (N) 290 mg / kg, effective phosphorus content 115.1mg/kg and quick potassium content 690.4mg/kg.

The variety of tea trees tested is Buddha fragrant, about 8a years old, and the tea garden management is consistent. Commercial organic fertilizer, oil dry organic fertilizer no. 1. Oil dry organic fertilizer no. 2 (add 0.05%Y2 powder), oil dry organic fertilizer no. 3 (0.05%Y2 powder, 0.1% ã -aminobutyric acid), oil dry organic fertilizer no. 4 (0.05%Y2 powder, 0.5% polyglutamate acid), oil dry organic fertilizer no. 5 (add 0.05%Y2 powder, 0.1% ã -aminobutyric acid, 0.5% polyglutamate acid), microbial agent.

Experimental design

T1, T2, T3, T4, T5 and T6 were treated, and the combination and amount are shown in Table 1. The area of each treatment area is 4 mu, without repetition; protection area and subdivision, and the interval of different treatment areas is 2m; except nutrients, the tea garden management is consistent.

Sample collection and analysis method

Collection of soil samples

Before fertilizing a basic soil, in each area with 0-20cm soil mixed samples 1.0kg, each area 5 points, remove the fresh soil sample gravel and plant stubble debris mixed 5 mixed samples evenly divided into two, some soil samples 4℃ refrigerator for soil microbial determination. The other part of air drying treatment for the determination of soil physical and chemical properties, soil organic carbon and soil enzyme activity.

Determination of soil physical and chemical properties

The physicochemical properties of soil included soil pH, organic matter, rapid nitrogen, rapid phosphorus and rapid potassium.pH value was measured by pH meter, organic matter by potassium heavy complex plus heat capacity, quick nitrogen by alkaline nitrogen diffusion, quick phosphorus by photoelectric colorimetry, and quick potassium by NH4OAc extraction flame photometry.

Quality determination of tea leaves

Two rounds of spring tea will be picked in April 2023, and gently trimmed after picking. Two rounds of summer tea will be picked from late July to early August 2023, and one round of autumn tea will be picked in late October 2023.The samples of one bud and two leaves were fixed by steaming method, and the content of tea polyphenols, free amino acids and caffeine was determined according to GB / T8313-2018.

Methods for analyzing microbial functional diversity of soil microorganisms. Soil microbial genomic DNA was extracted from TM kits, then the quality of extracted genomic DNA was measured by 80% agarose gel electrophoresis, and DNA was quantified using a UV spectrophotometer.PCR products were detected by agarose gel electrophoresis at a concentration of 1.0% in triplicate per sample. The PCR products were recovered using AxyPrepDNA gel recovery kit gel and eluted by Tris-HCl. PCR products from the same specimen were mixed and detected by 2% agarose gel electrophoresis.

Data analysis

All data were statistically analyzed using WPS Office and IBM SPSS Statistics27 software and the data in the table are mean with a significance level of 0.05. Data entry was conducted using WPS Office, the average and standard deviation of data from each cell were obtained, and the data with large errors were discarded. After each three sets of data, one-way ANOVA was used to analyze significant differences for each treatment. OTU was annotated by taxonomic annotation using the bacterial

16SrRNA Silva database and fungal ITSUNITE database as reference.

RESULTS AND DISCUSSION

Effects of different types of organic fertilizer on soil nutrients in tea garden

The influence of different organic fertilizer and chemical fertilizer distribution on the physical and chemical properties of soil foundation is shown in Table 2. The results show that, Compared with conventional fertilization (T1), Soil pH increased from T 2 to T 5 treatment, The most significant increase in PH values after T4 treatment. The T6 treatment decreased the PH value; In contrast to T1, The T2 treatment significantly increased the organic matter content in the soil. Other organic fertilizer treatment has reduced the content of organic matter; In contrast to T1, Except for the 14.47% reduction in soil hydrolysis N content in T 6 treatment; other organic fertilizer treatment increased the soil hydrolyzed nitrogen content. T3 treatment improved the most significant soil hydrolyzed nitrogen content, Up by 11.07%; In contrast to T1, In T 2 to T 6 treatment. Reduced by 23.44%, 48.52%, 62.5%, 31.25% and 43.59%, respectively; In contrast to T1, Both T 2 to T 6 decreased the quick potassium content in the soil. The reductions were 21.9%, 134.2%, 74.9%, 183%, and 152.7%, respectively. Among them, T2, T3 and T6 have the most obvious effect on soil basic physical and chemical indexes.

Soil is the basis of the growth and development of tea trees, and soil nutrients are closely related to the growth and development of tea trees and the yield and quality of tea leaves.Reasonable control of the soil environment of tea tree growth has a positive effect on improving the yield and quality of tea leaves (Wang et al., 2024b). The application of organic fertilizer to improve the soil organic matter content, improve the soil traits, soil fertilizer effect is obvious (Nishimura et al., 2024). The content of organic matter, effective phosphorus and hydrolyzed nitrogen is linearly correlated with the content of tea free amino acids and tea polyphenols and other quality indicators (Che et al., 2024, Li et al., 2024, Khan et al., 2024, Khan et al., 2023). The application of organic fertilizer can significantly improve the soil fertility index, and then improve the quality of tea (Yang et al., 2023). The application of organic fertilizer can effectively regulate the uniform supply of soil nutrients, increase the activity of microorganisms, improve the utilization rate of crop nutrients, and reduce the utilization amount of chemical fertilizer (Li et al., 2021). The long-term unreasonable use of chemical fertilizer will destroy the soil structure and lead to soil acidification. The optimal PH value of tea garden soil is generally between 5.0 and 6.5, and the low soil pH value has a negative impact on the growth of tea trees (Liu et al., 2024).

Comparison of soil microbial diversity in different fertilization treatments

As can be seen from Figure 1, the number of bacterial OUT in all samples of each treatment was 202. Compared with T1, except for the T 3 fertilization treatment, different fertilization treatments increased the OUT number of soil bacteria, and the T2 fertilization treatment increased the OUT number of bacteria. The number of fungal Feature common to each treatment was 49, and the number of OUT's unique to the T1, T2, T3, T4, T5, and T6 treatments was 219,242,258,228,263, and 219. Compared with T1, the amount of Feature in T 6 remained unchanged, and the number of fungal Feature from T 2 to T5 increased, including the number of fungal Feature with T 3 and T 5.

As shown in Figure 2, the dominant bacterial species at the portal level in the soil are Proteobacteria (Proteobacteria), Acidobacteria (Acidobacteriota), Actinobacteria (Actinobacteriota), and Budomomonas (Gemmatimonadota). Compared to the T1, T 4 and T 5 fertilization treatment increased proteobacteria by 2.88% and 6.02% respectively. Except for the T5 fertilization treatment. All the rest of the fertilization treatment increased the acid bacterium phylum level, Increased by 3.47%, 13.72%, 5.13% and 2.83%, respectively. T 2 to T 6 fertilization treatments reduced the Actinobacteria level, The most significant reduction in the T 4 and T5 fertilization treatments, It decreased by 5.03% and 4.39%, respectively; Most significantly decreased levels of Budulomonas treated with T 4 and T 5 fertilization, It decreased by 4.22% and 3.23%, respectively. The dominant fungal groups in the soil are ascomycota (Ascomycota) and Basidiomyces (Basidiomycota), accounting for more than 80% of the total. Compared with T1, except T 2, the content of Ascomycota was decreased in T 2,43.45%; except for T6 and T 5, the content of Basidiomycota was increased by 0.5%, 7.28% and 27.88% respectively; for T 2, and T6, Basidiomycota.

According to Figure 3, Genus level bacteria: Rhizobium (Haliangium), Arthrobacter (Arthrobacter), Bryophytica (Bryobacter), Budomonas (Gemmatimonas), Bradyrhizobium (Bradyrhizobium), Compared to the T1, The T3 fertilization treatment significantly increased the relative abundance of Haliangium, To ed Arthrobacter relative abundance. The T6 fertilization treatment enhanced the relative abundance of Bryobacter, Reduced Gemmatimonas relative abundance. The T4 fertilization treatment enhanced the relative abundance of Bradyrhizobium. Reduced the relative abundance of Arthrobacter and Gemmatimonas.genus level fungi: fungi (Humicola), cosa (Plectosphaerella), muria pestis (Saitozyma), mycoaria (Cladosporium), Compared to T1, The T3 fertilization treatment significantly increased the relative abundance of Humicola, Significantly reduced Plectosphaerella relative abundance, The T6 fertilization treatment increased the Saitozyma abundance most significantly, Reduced the relative abundance of Cladosporium.

Previous studies compared and analyzed the number and species changes of bacterial and fungal OTU under different fertilization treatments, and found that in addition to the significant increase of bacterial or fungal OTU number under specific fertilization treatment. Each fertilization treatment also significantly affected the microbial community structure at the soil phylum level and genus level (Guo et al., 2024, Ahmed et al., 2024, Ullah et al., 2022, Rashid et al., 2022). Specifically, the relative abundance of bacterial species, such as Proteobacteria, Acibacter, and fungal species, such as Ascomycota and Basidiomyce, were differentiated under different fertilization treatments, while the relative abundance of rhizobia, Arthobacterium and fungi at the genus level were also changed by the fertilization treatment (Pu, 2024). These findings not only reveal the specific influence mechanism of organic fertilizer on the microbial diversity and community structure of tea soil, but also provide a scientific basis for optimizing the fertilization strategy in tea cultivation.

Influence of different kinds of organic fertilizer on the biochemical quality of tea

The application of organic fertilizer helps to improve the soil nutrient supply, improve the efficiency of soil nutrient supply, and reduce the amount of mineral fertilizer. Organic fertilizer has a significant impact on the improvement of tea quality. The content of the internal chemical components of tea polyphenols, free amino acids, water extract, and caffeine is very important to the quality of tea. The content of polyphenols in tea determines the richness of tea, which is an important health ingredient in tea, but its high content will also lead to bitter taste.The content of tea polyphenols, free amino acids, water extract, phenol ammonia ratio and other substances is closely related to the quality of tea. Too high tea polyphenols content will lead to bitter tea, and the lower the phenol ammonia ratio, the higher the quality of tea (Guo et al., 2021).

According to Table 3, the effects of tea water extract, tea polyphenols, free amino acids, and caffeine content were significantly different under different treatments. Tea polyphenols are the complex of polyhydroxyphenolic compounds in tea. They are composed of more than 30 kinds of phenolic substances. They are the main components that determine the color, aroma, flavor and efficacy of tea, and are sensory bitter (Wang et al., 2020).Compared with T1, the content of tea polyphenols decreased after each fertilization treatment. The free amino acids in tea have caramel aroma and fresh taste similar to monosodium glutamate, and the content of free amino acids has a positive correlation with the quality of tea (Yang, 1991). Compared with T1, the total amount of free amino acids increased from T 2 to T 6, with the highest increase in T 6. Caffeine is a bitter substance, which can stimulate the central nerve, enhance the excitement process of the cerebral cortex, so as to stimulate the spirit, improve thinking, improve efficiency (Yin and Liu, 2013). Compared with T1, the caffeine content increased after T2 and T3 fertilization treatment, with the most significant increase in T 3, and slightly decreased from T 4 to T 6 fertilization treatment. Tea water extract is the general term of various substances soluble in water in tea leaves, and it is a comprehensive index reflecting the quality of tea leaves. Compared with T1, the T 2 treatment was significantly reduced in terms of water extract content, with no significant differences between the other treatments. In general, the effect of T3 and T 6 fertilization treatment is better.

Relationship between tea quality and soil nutrients of different types of organic fertilizer

As can be seen from Table 4, organic fertilizer can provide abundant carbon and nitrogen substances for the soil, which is of great significance to improving soil nutrients and improving the quality of tea (Wang, 2024). Different kinds of organic fertilizer also have different effects due to their different product quality. There is a close and significant correlation between the application of different kinds of organic fertilizer and the improvement of soil physical and chemical properties and the improvement of tea quality (Wang et al., 2024a). There is a significant positive correlation between the content of hydrolyses nitrogen in soil and the content of caffeine in tea, meaning that the increase of nitrogen supply helps to increase the content of caffeine in tea. However, the content of quick potassium is a significant negative correlation with the total amount of free amino acids in tea, suggesting that the change of potassium level may have a reverse effect on the accumulation of amino acids. Moreover, the content of soil organic matter was not only significantly positively correlated with the caffeine content of tea, but also with the total amount of free amino acids, showing the complex role of organic matter in regulating the chemical composition of tea (Wang et al., 2020). At the same time, the content of effective phosphorus is significantly positively correlated with the content of tea polyphenols in tea, and negatively correlated with the total amount of free amino acids. Which further emphasizes the positive role of phosphorus on the formation of characteristic flavor components of tea. In conclusion, the application of different kinds of organic fertilizer has a profound impact on soil physical and chemical characteristics and tea quality (Guo et al., 2021). Through the reasonable selection and application of organic fertilizer, it can not only effectively enhance the soil fertility, stimulate the activity of soil microorganisms, but also can significantly improve the quality characteristics of tea, so as to win a stronger competitiveness for tea products in the market.

Table 1. Treatment and fertilization methods

Treatments	base fertilizer	top application
T1	Commercial organic fertilizer 200kg / mu (local conventional fertilization)	Microbial agent 2kg / mu, diluted 500 times the application
T2	Oil-dry organic fertilizer no. 1,200kg / mu	
T3	Oil-dry organic fertilizer no. 2,200kg / mu	
T4	Oil-dry organic fertilizer no. 3,200kg / mu	
T5	Oil-dry organic fertilizer no. 4,200kg / mu	
T6	Oil-dry organic fertilizer no. 5,200kg / mu	

Table 2. Effects of different fertilization treatments on soil nutrients in tea plantations

Treatments	pH price	organic matter	conductivity	hydrolyzable nitrogen (N)	Effective phosphorus (P)	Quick-acting potassium (K)	unit weight
T1	4.46±0.23a	105.86±1.78ab	211.00±1.51a	325.21±1.77d	167.89±1.87a	674.50±5.25a	0.90±0.04a
T2	4.61±0.25a	110.13±2.06a	133.20±2.25c	332.87±3.15ab	144.45±2.29b	652.60±2.14b	0.87±0.03a
T3	4.61±0.21a	100.83±2.03bc	127.20±1.99d	336.28±1.51a	119.37±2.84d	540.30±1.97d	0.77±0.01c
T4	4.83±0.20a	95.21±3.39d	103.20±0.34e	326.91±1.56cd	105.39±2.76e	599.60±2.22c	0.78±0.03c
T5	4.49±0.31a	96.75±1.69cd	130.60±0.64cd	331.17±0.11bc	136.64±2.04c	491.50±1.61f	0.86±0.01ab
T6	4.35±0.06a	84.86±1.41e	192.20±2.93b	310.74±1.51e	124.30±2.14d	521.80±2.73e	0.80±0.02bc

Note: The same lowercase letters in the same column in the table indicate no significant difference between treatments, and different lowercase letters indicate no different difference (P <0.05).

Table 3. Effect of different fertilization treatments on the biochemical quality of tea leaves

Treatments	aqueous extract	tea polyphenols	Total amount of free amino acids	theine
T1	43.49±0.21a	11.87±0.23a	3.72±0.35d	3.81±0.09b
T2	39.94±1.22b	11.61±0.42ab	4.13±0.18cd	3.90±0.07ab
T3	42.24±0.45a	11.76±0.12ab	4.23±0.00bc	4.03±0.01a
T4	41.98±0.67a	10.85±0.26c	4.52±0.18abc	3.79±0.12b
T5	41.84±0.35a	11.49±0.09ab	4.65±0.07ab	3.78±0.08b
T6	41.89±0.81a	11.19±0.01bc	4.70±0.06a	3.69±0.08b

Note: The same lowercase letters in the same column in the table indicate no significant difference between treatments, and different lowercase letters indicate no different difference (P <0.05).

Table 4. Relationship between tea quality and soil nutrients applied with different biological organic fertilizers

	pH price	organic matter	conductivity	hydrolyzable nitrogen (N)	Effective phosphorus	Quick-acting potassium	unit weight
aqueous extract	-0.223	-0.199	0.457	-0.173	0.173	0.003	0.059
tea polyphenols	-0.47	0.525	0.376	0.435	0.659*	0.24	0.588*
Total amount of free amino acids	0.136	-0.696*	-0.373	-0.357	-0.659*	-0.763**	-0.600*
theine	0.419	0.599*	-0.367	0.720**	-0.008	0.138	-0.22

*. At the 0.05 level (two-tailed), the correlation was significant.**. At the 0.01 level (two-tailed), the correlation was significant.

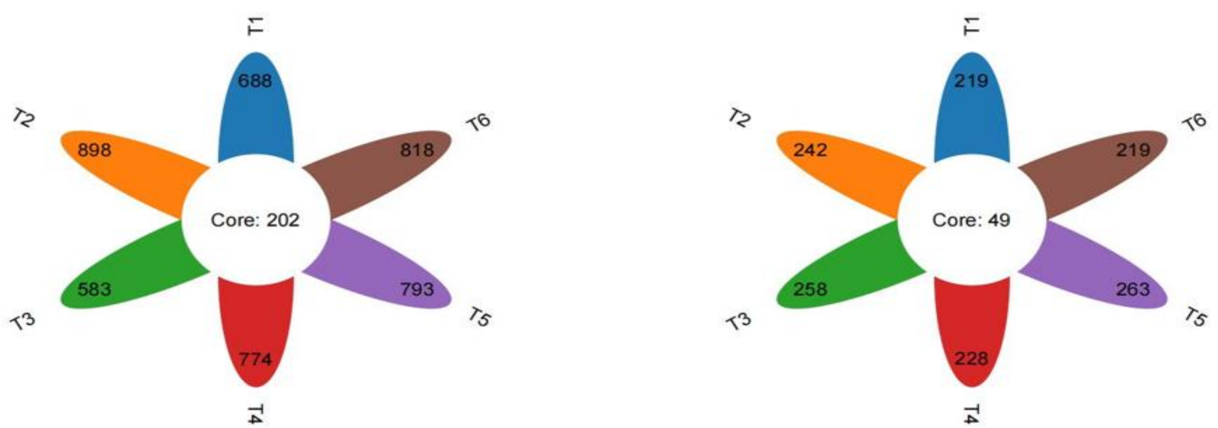

Figure 1. Effect of different fertilization treatments on the number of bacteria and fungi in the soil

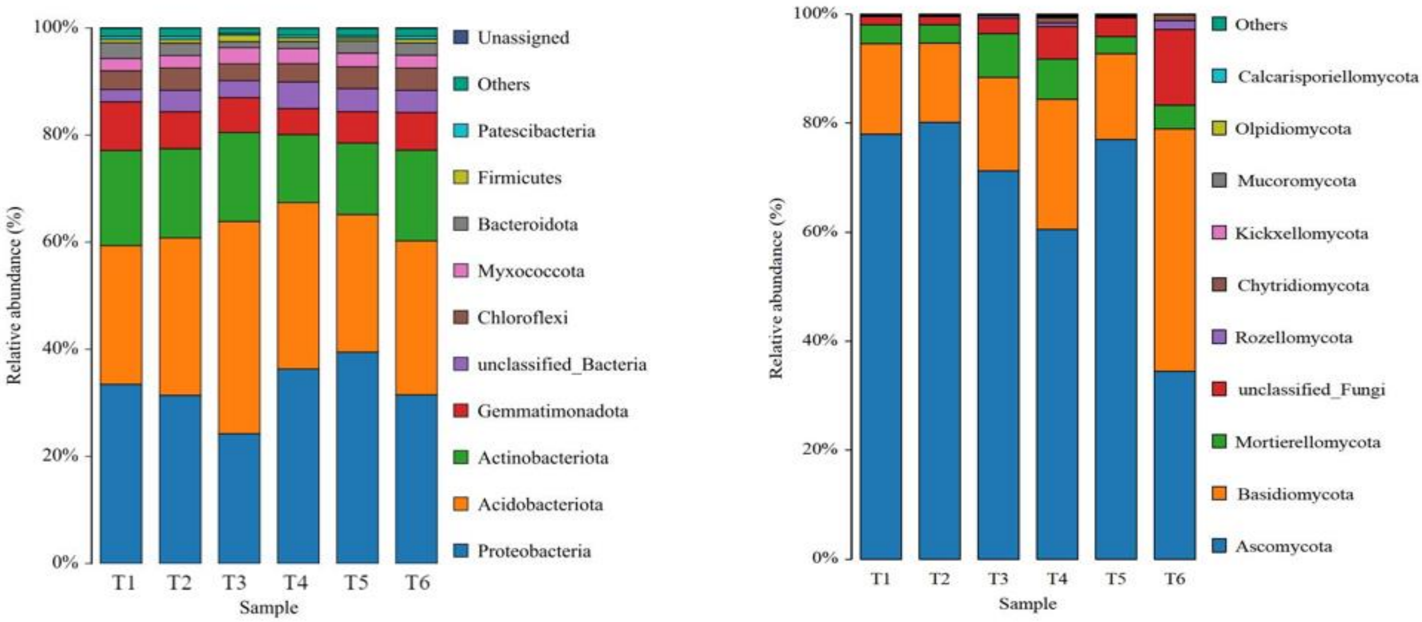

Figure 2. Effects of different fertilization treatments on bacteria and fungi at soil phylum level

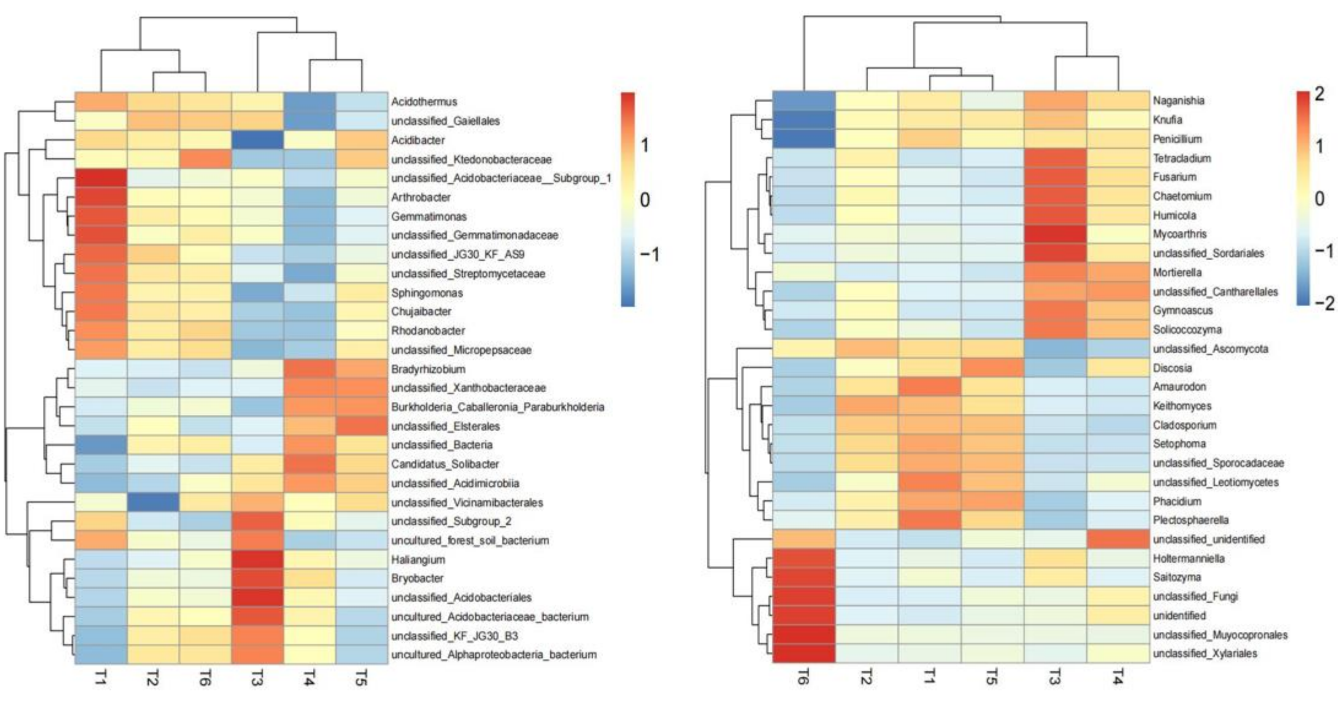

Figure 3. Effects of different fertilization treatments on bacteria and fungi at the genus level

CONCLUSION

This study demonstrated that, compared to T1, the T2 treatment significantly improved soil organic matter, while the other treatments resulted in a decrease. Except for T6, all organic fertilizer treatments increased hydrolytic nitrogen, with T3 showing the highest increase of 11.07%. T2 reduced the water extract content, while T6 significantly increased free amino acids in the leaves. T3, on the other hand, enhanced the caffeine content in tea leaves. Hydrolytic nitrogen was found to have a positive correlation with tea caffeine, while rapid potassium showed a negative correlation with free amino acids. Soil organic matter exhibited complex regulation of tea composition, promoting caffeine production while suppressing free amino acids. Effective phosphorus positively influenced tea polyphenols and negatively affected free amino acids, highlighting phosphorus's role in enhancing tea flavor. Overall, the application of organic fertilizer alleviated soil acidification in tea gardens, promoted tea tree growth, improved tea quality, and enriched soil nutrients. Among the treatments, T3 was the most effective, followed by T6.

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