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Article

Accumulation of trace elements in tea under different soil conditions and the biomechanics-related mechanism of their influence on plant antioxidant enzyme activities

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Abstract: China is an important tea-growing country, and top quality tea, specialty tea and other high-quality tea is more and more favored by the tea industry, so that the production demand is rising year by year. The formation of high quality tea requires suitable soil factors, and soil is one of the two key factors affecting the production of high quality tea. The physicochemical properties and nutrient content of different soils can significantly impact the intracellular processes within tea plants. The absorption and transportation of trace elements such as selenium in tea roots are mediated by specific transporter proteins. These proteins operate based on molecular mechanisms and biomechanical forces that drive the movement of ions across cell membranes. In this paper, we utilize GPS technology to design the distribution area of the test tea production area, and adopt the S-type method to collect the soil of tea differential land in different ecological environments, to explore the physicochemical properties, nutrient content, pH value and water management of different soil types. The whole trace elements and effective trace elements in tea were determined through experiments. The antioxidant enzyme activity of tea was measured by TBA and other methods. The results showed that after planting in different soils, the selenium content of autumn tea was 0.08%, 0.04%, 0.04% in loamy soil > sandy soil = clay soil, respectively. The amount of selenium carried out was sandy soil > loamy soil > clay soil, and the amount of selenium carried out increased by 142.37 kg and 94.97 kg after comparing two by two. Compared with the tea leaves with added trace elements, the T-AOC of the tea leaves without added decreased by 18.75%, 14.20%, 28.06%, and 35.14%. These findings highlight the importance of understanding the cellular and molecular processes in tea plants influenced by soil conditions and trace elements for optimizing tea quality and production.

Keywords: S-collection; physicochemical properties; active state trace elements; antioxidant enzyme activity; cellular molecular biomechanics

1. Introduction

Soil is one of the necessary conditions for the survival and growth of the tea tree. It is the place where the tea tree grows and develops and absorbs nutrients. Tea garden soil contains organic matter and mineral elements required for the growth of tea trees. Among the mineral elements necessary for the growth of tea trees, major elements include nitrogen, phosphorus, and potassium; secondary elements include calcium, magnesium, and sulfur; and trace elements include iron, manganese, boron, zinc, copper, and molybdenum [1,2]. Different soil nutrients, due to differences in soil conditions, farming systems, effective amounts, etc., usually affect the growth of tea trees. Meanwhile, various soil nutrients have irreplaceable roles in the growth of tea trees [3–5]. Therefore, according to the physiological needs of the tea tree, scientifically and reasonably controlling tea garden soil to create a suitable soil environment for the growth of tea trees, improving tea yield, protecting tea quality, and enhancing the economic benefits of tea plantations is of great significance.

External environmental stresses cause damage to plants mainly because adversity stresses lead to excessive production of reactive oxygen radicals [6]. There are two sets of antioxidant systems in plants to scavenge the excess free radicals generated by stress and maintain normal physiological metabolism, namely the antioxidant enzyme system and low molecular weight substances [7,8]. The activity of the plant antioxidant system is at a relatively low level in the natural growth state. Once subjected to environmental stresses within its own tolerance range, the activity of the antioxidant system will increase [9,10]. When the degree of stress exceeds the plant's own tolerance range, the antioxidant system will be damaged [11]. Trace elements can directly regulate the production and reduction of reactive oxygen radicals and enhance the antioxidant capacity of plants, which is an effective mechanism for plants to alleviate adversity stress [12,13].

Wang explored the accumulation capacity and mechanism of selenium in the plant body and analyzed its effects on physiological activities such as metabolism and quality regulation of tea. It is indicated that selenium can optimize the ratio of high-quality compounds in the plant body, increase the levels of related antioxidant enzymes and phytohormones, and promote the healthy growth of tea [14]. Zaman investigated the effects of foliar application of various trace elements on the internal biochemical composition of black tea. Based on the understood mechanism of action, tea varieties suitable for specific uses can be screened by regulating oxidizing substances during tea processing [15]. Xu discussed the effect of foliar application of glucose selenium (GLN-Se) on summer and autumn tea. The results of the study showed that GLcN-Se effectively improved the antioxidant system of tea leaves, thereby increasing its photosynthesis and yield. It also improved the internal non-volatile and volatile components, enhancing the nutritional quality and sensory properties of tea [16]. Ye measured the minerals and active ingredients in green tea samples with different selenium contents and found that selenium had a significant effect on the accumulation of minerals and polyphenols in tea. It also brought many health benefits to consumers. The study is of great theoretical significance for the development of selenium-enriched green tea [17]. Musial examined the bioactive compounds within green tea. Catechins, as its main antioxidants, are affected by the type and origin of green tea. The number of hydroxyl groups and characteristic structural motifs of catechins have a great impact on its antioxidant activity [18]. Sun analyzed and compared the mineral nutrient content, antioxidant enzyme activity, and quality parameter content of tea leaves from different selenium sources. It is pointed out that spraying selenium on tea leaves not only promotes the uptake of mineral nutrients such as nitrogen, phosphorus, and potassium but also significantly increases the antioxidant enzyme activities. Yeast selenium treatment has the most significant effect [19]. He determined the proportion of antioxidant capacity contribution of the characteristic compounds of teas by using the DPPH and HPLC methods to better understand the antioxidant activity of the composite tea polyphenol fractions. It was found that gallocatechin catechin gallic acid had the highest antioxidant capacity [20].

In this paper, soil sample collection points were designed in the tea-origin distribution area in the Southern Anhui region of China. GPS was used to locate the collection points, and the S sampling method was adopted to collect the soil from tea origins in different ecological environments. After a series of operations, the collected soil samples were placed in a desiccator for preservation. The physicochemical properties of different soil types were explored, and the soil sample conditions for the experiment were rationally selected. At the same time, the soil's single-nutrient content, pH value, and water management were gradually analyzed to further determine the experimental environment. Methods for determining total trace elements and available trace elements in tea were proposed respectively. Trace elements in tea were prepared to obtain the antioxidant enzyme activities of plants based on the physiological indexes of tea seeds. We analyzed the effect of different soil conditions on the accumulation of nitrogen, phosphorus, potassium, and other trace elements in tea and the effect of the accumulation of trace elements on the antioxidant enzyme activity of plants.

2. Materials and methods

2.1. Soil samples

In order to ensure the representativeness of soil sample collection, the soil sample collection points were designed according to the distribution area of tea origins in the Southern Anhui region of China. GPS was used to locate the collection points, and an S-shaped sampling method was used to collect the soil of tea origin in different ecological environments [21]. A stainless steel spade was used at each point to take soil mixture samples and the collected samples were packed in clean cloth bags. Air drying was carried out in the laboratory while removing non-soil materials such as plant residues, large gravels, etc., to avoid contamination by dust and acids and alkalis. The air-dried samples were mixed thoroughly and then sopped with a wooden stick to pass through a 1 mm nylon sieve, and some soil samples were taken out in quadrature to be further finely ground with an agate port and passed through a 0.25 mm nylon sieve, and the sieved samples were placed in a sealed bag and labeled, and stored in a desiccator for spare use.

2.1.1. Soil types and their physico-chemical properties

Soil type is an important factor in determining the growing environment of tea. The physicochemical properties of different soil types have different effects on the growth and development of tea. Sandy soil has good drainage and permeability, which is conducive to root growth. However, its ability to retain water and fertilizer is poor. Loamy soil has both good drainage and water retention capacity and is a more ideal planting soil. Clay soil is good at retaining water and fertilizer but has poor permeability, which may lead to root hypoxia. Reasonable selection and improvement of soil type can effectively promote the growth of tea.

2.1.2. Soil nutrient content

Nutrients in the soil are the basis for the growth and development of tea, and the main nutrients such as N, P, and K play different roles in the growth process of tea. N promotes the growth of tea leaves, P helps root development and fruit maturation, and K improves disease resistance and drought tolerance of tea. Different soil nutrient levels directly affect the growth rate, leaf size and yield of tea. Therefore, scientific fertilization and soil nutrient management are the keys to achieving high yield.

2.1.3. Soil pH

Soil pH value affects the effectiveness of nutrients and the absorption capacity of tea. Tea is suitable for growth in slightly acidic to neutral soils, and too low or too high a soil pH can affect nutrient uptake, which in turn inhibits tea growth and reduces yields [22]. Elements such as Al and Mn may reach toxic levels in acidic soils, while the effectiveness of elements such as P, Fe and Zn is reduced in alkaline soils. Adjusting soil pH to keep it within the appropriate range is necessary to ensure the healthy growth of tea.

2.1.4. Soil moisture management

Soil moisture management is crucial for the growth of tea. Suitable moisture conditions can promote tea root development and nutrient uptake [23]. Excessively dry soil will lead to tea dehydration, affecting photosynthesis and physiological metabolism, and excessively wet soil may cause root hypoxia and increase the risk of pests and diseases. Therefore, rational irrigation and drainage are important to ensure the normal growth of tea and increase the yield. By adjusting the frequency and mode of irrigation and keeping the soil moisture suitable, the tea growing environment can be significantly improved.

2.2. Determination of trace elements in tea

Tea is the most popular natural health drink in the world today and one of the most important cash crops in tropical and subtropical regions. Tea contains many trace elements (Fe, Mn, Cu, Zn, Mo, B, etc.) that are beneficial to human health, of which nearly 15.2% Fe, 28.8% Mn, 31.8% Cu, and 50.7% Zn can be dissolved in tea, so tea drinking will become an important source of micronutrients for the human body [24]. Supplementation of essential micronutrients through tea drinking can satisfy the human body’s demand for water and also supplement essential micronutrients. Soil, as the main place for the growth and reproduction of tea trees, provides a large amount of nutrients and water for tea trees.

2.2.1. Determination of whole Fe, Mn, Cu, Zn, Mo in tea

Weigh 0.1000 g of the sample (accurate to 0.0002 g) in a 25 mL PTFE crucible. Add a little water to moisten it. Carefully add 3 mL of concentrated nitric acid and then 1 mL of perchloric acid. Put it into a high-pressure sealed canister and place it in an oven. Set the temperature to 180 ℃ and perform ablation for 3 hours. After the ablation is completed, ventilate and cool down to room temperature. Transfer it to a 50 mL centrifugal tube and then fix the volume with ultrapure water. Shake the sample well and analyze it on an inductively coupled plasma mass spectrometer (ICP-MS).

2.2.2. Determination of Fe, Mn, Cu, Zn and Mo in the effective state of tea

Weigh 10.0g of air-dried sample through a 2mm nylon sieve in a plastic bottle, add 20.0mL of EDTA extractant, oscillate at 180r/min for 2h at room temperature, filter immediately, and determine by atomic absorption spectrophotometer. The analysis of boron in its effective state is determined using the boiling water extraction methylpropylamine colorimetric method.

2.3. Determination of plant antioxidant enzyme activities

2.3.1. Test methods

Seeds of uniform size and consistency were screened from each tea variety, rinsed with distilled water and divided into five groups, which were soaked in 0 (clear water control, CK), 25, 50, 100 and 200 *mg*/*kg* manganese sulphate solution at room temperature for 12 h. Afterwards, they were arranged in a germination box lined with fine sand, which was placed in the light incubator at 25 ℃ for germination culture, and germination was observed on a daily basis. After the seeds sprouted, physiological indexes were measured.

2.3.2. Measurement items and methods

Physiological indicators of tea seeds include malondialdehyde (MDA), superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT). Among them, the content of malondialdehyde (MDA) was determined by TBA colorimetric method. The activity of superoxide dismutase (SOD) was determined by tetrazolium blue (NBT) photo-reduction method. The activity of peroxidase (POD) activity was determined by guaiacol method. And The activity of catalase (CAT) was determined by potassium permanganate titration method [25].

2.3.3. Measurement of influence of trace elements on oxidase activity

Polycopper oxidases CumA and CopA were divided into several equal parts in their respective optimal pH buffer liquid systems. Then, 2 mM of Cu ions, Ni ions, Mn ions, Zn ions, Mg ions, Ca ions, Mn ions, and Fe metal ions were added respectively. The mixtures were stored at 4℃ for 20 minutes. After that, the activity of plant antioxidant enzymes was determined, with ABTS as the substrate for polycopper oxidase CumA and DMP as the substrate for polycopper oxidase CopA. Taking the maximum enzyme activity as 100%, the relative enzyme activity was mapped with different divalent metal ions. Each assay was repeated three times. Regarding the effect of divalent metal ions on the enzyme activities of polycopper oxidases CumA and CopA, it should be noted that Cu ions with a final concentration of 0.1 mM should not be added during the induction of expression to avoid interfering with the subsequent determination.

3. Analysis of test results

3.1. Effect of different soil conditions on the accumulation of micronutrients in tea leaves

3.1.1. Nitrogen

Table 1 shows the nitrogen content of tea micronutrients in different soil conditions. After different soil treatments, for spring tea, the level of nitrogen content showed the order of clay soil > loam soil > sandy soil. The nitrogen content of spring tea increased by 0.74% and 1.3%. The Carrying capacity showed clay soil (1.63%) <loamy soil (2.91%) < sandy soil (4.98%).

For fall tea, the level of nitrogen content also showed the order of clay > loamy soil > sandy soil. The nitrogen content of fall tea increased by 1.04% and 1.07%. The highest carryover of 503.96 kg/mu was found in clay soil.

Tea nitrogen agronomic efficiency and bioproductivity showed significant differences between different soil treatments and there was also a strong regularity. The spring and fall tea nitrogen agronomic efficiency and bioproductivity of clay soil treatments were higher than those of sandy and loamy soil treatments, indicating that adding trace elements and microorganisms to clay soil can improve the efficiency of tea nitrogen utilization.

Table 1. Nitrogen content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil alkali solution nitrogen mg/kg	Fertilizer utilization/ %	Physiological utilization kg/kg	Agricultural efficiency kg/kg	Deflection force kg/kg
Spring tea	Sandy soil	5.31 ± 0.41	1.63 ± 0.21	104.66 ± 9.48	/	/	/	/
	Loamy	6.61 ± 0.64	2.91 ± 0.32	128.36 ± 4.65	/	11.52 ± 2.18	/	/
	Clay	7.35 ± 0.26	4.98 ± 0.12	213.15 ± 25.79	45.36 ± 1.65	14.48 ± 1.32	5.31±0.32	8.52 ± 0.31
Autumn tea	Sandy soil	3.68 ± 0.01	195.52 ± 5.89	123.85 ± 1.96	/	/	/	/
	Loamy	4.75 ± 0.08	378.96 ± 6.15	142.65 ± 2.78	/	3.12 ± 0.91	/	/
	Clay	5.79 ± 0.39	503.96 ± 32.55	159.48 ± 6.28	40.36 ± 0.34	3.86 ± 0.61	4.74 ± 0.31	7.92 ± 0.36

3.1.2. Phosphorus

Table 2 shows the phosphorus content of tea micronutrients in different soil conditions. After different soil treatments, the physiological utilization of phosphorus in spring tea ranged from 197.48 to 213.15 kg/kg. The level of physiological utilization was in the order of loamy soil > clay soil. The physiological utilization increased by 15.67%. The level of physiological utilization of phosphorus in autumn tea showed that for clay it was 80.26 kg and for loam it was 52.59 kg. And the order of physiological utilization of phosphorus was clay > loamy. The agronomic efficiency and bioproductivity of spring tea phosphorus based on clay soil culture were 20.65 kg and 33.65 kg, respectively. Those of fall tea phosphorus were 22.36 kg and 37.98 kg, respectively.

Table 2. Phosphorus content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil effective phosphorus mg/kg	Fertilizer utilization/ %	Physiological utilization kg/kg	Agricultural efficiency kg/kg	Deflection force kg/kg
Spring tea	Sandy soil	0.59 ±0 .03	148.12 ± 1.96	4.56 ± 1.12	/	/	/	/
	Loamy	0.52 ± 0.03	234.48 ± 5.36	5.26 ± 0.46	/	213.15 ± 22.36	/	/
	Clay	0.53 ± 0.04	354.88 ± 8.26	4.04 ± 0.36	10.26 ± 0.48	197.48 ± 7.98	20.65 ± 1.32	33.65 ± 1.38
Autumn tea	Sandy soil	0.26 ± 0.05	13.05 ± 1.32	4.89 ± 0.65	/	/	/	/
	Loamy	0.34 ± 0.05	25.78 ± 1.33	4.27 ± 0.26	/	52.59 ± 6.18	/	/
	Clay	0.31 ± 0.03	28.26 ± 1.68	4.98 ± 0.65	10.94 ± 0.15	80.26 ± 3.66	22.36 ± 1.34	37.98 ± 1.25

The agronomic efficiency and bioproductivity of tea phosphorus differed significantly between different soil treatments and also showed a very strong regularity. The spring and fall tea phosphorus agricultural efficiency and bioproductivity of clay soil treatments were significantly higher than those of sandy and loamy soils, indicating that clay soil has the optimal performance in terms of phosphorus agricultural efficiency and bioproductivity.

3.1.3. Potassium

Table 3 shows the magnesium content of tea trace elements in different soil conditions. The magnesium agricultural efficiency of spring tea was 443.66 kg, and the magnesium agricultural efficiency of autumn tea was 450.65 kg. The fertilizer utilization of the clay soil was more obvious in enhancing the agricultural efficiency and the magnesium utilization of the soil after the addition of fertilizer additives could enhance the magnesium treatment effect in the soil.

Table 3. Potassium content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil effective potassium mg/kg	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg	Deflection force kg/kg
Spring tea	Sandy soil	2.48 ± 0.09	0.64 ± 0.05	157.58 ± 70.65	/	/	/	/
	Loamy	2.59 ± 0.05	1.18 ± 0.06	204.96 ± 6.48	/	38.96 ± 2.24	/	/
	Clay	2.57 ± 0.03	1.78 ± 0.09	154.63 ± 6.59	23.18 ± 1.63	37.98 ± 0.75	8.86 ± 0.64	14.25 ± 0.65
Autumn tea	Sandy soil	2.19 ± 0.16	106.65 ± 4.36	208.99 ± 4.25	/	/	/	/
	Loamy	2.28 ± 0.09	176.65 ± 2.96	267.96 ± 45.36	/	9.62 ± 0.78	/	/
	Clay	2.24 ± 0.06	203.48 ± 1.35	234.59 ± 24.96	22.36 ± 0.18	12.97 ± 0.65	8.65 ± 0.57	15.15 ± 0.58

3.1.4. Magnesium

Table 4 shows the magnesium content of tea trace elements in different soil conditions. The magnesium agronomic efficiency of spring tea was 443.66 kg, and the magnesium agronomic efficiency of autumn tea was 450.65 kg. The fertilizer retention effect of the clay soil was more obvious to enhance the agronomic efficiency, and the magnesium utilization of the soil after the addition of fertilizer additives could enhance the magnesium treatment effect in the soil.

Table 4. The magnesium content of the trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil exchange magnesium mg/kg	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	0.64 ± 0.03	184.69 ± 21.36	179.42 ± 45.26	/	/	/
	Loamy	0.61 ± 0.08	264.85 ± 22.69	172.96 ± 30.65	/	234.59 ± 65.33	/
	Clay	0.91 ± 0.05	616.59 ± 24.36	158.96 ± 21.89	4.36 ± 0.34	98.26 ± 6.36	443.66 ± 26.48
Autumn tea	Sandy soil	0.59 ± 0.08	27.59 ± 3.96	234.96 ± 7.23	/	/	/
	Loamy	0.87 ± 0.02	67.85 ± 1.23	228.66 ± 10.63	/	20.36 ± 0.87	/
	Clay	1.05 ± 0.08	95.63 ± 6.23	175.69 ± 21.26	4.95 ± 0.12	23.18 ± 1.45	450.65 ± 26.54

3.1.5. Copper

Table 5 shows the copper content of trace elements in tea in different soil conditions, and the soil effective copper content in spring tea was in the order of loamy soil > clay soil > sandy soil, with the content ranging from 0.95 mg to 1.12 mg. The soil effective copper content of autumn tea was between 0.72 mg and 0.98 mg.

Table 5. Copper content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil effective copper content mg/kg	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	18.59 ± 0.19	0.48 ± 0.02	0.95 ± 0.18	/	/	/
	Loamy	23.48 ± 1.26	1.12 ± 0.08	1.12 ± 0.26	/	30.24 ± 2.36	/
	Clay	18.06 ± 0.96	1.26 ± 0.04	0.97 ± 0.08	1.97 ± 0.23	54.97 ± 0.89	0.94 ± 0.08
Autumn tea	Sandy soil	10.85 ± 1.23	52.94 ± 4.26	0.72 ± 0.15	/	/	/
	Loamy	13.48 ± 0.05	105.26 ± 2.26	0.98 ± 0.16	/	11.67 ± 0.68	/
	Clay	13.35 ± 0.26	118.96 ± 2.64	0.87 ± 0.15	1.59 ± 0.00	19.48 ± 0.56	0.84 ± 0.06

3.1.6. Zinc

Table 6 shows the zinc content of tea micronutrients in different soil conditions. The zinc content of spring tea in different soil conditions is shown as sandy soil > loamy soil > clay soil. The zinc content of spring tea varies between 0.9% and 2.73%. The zinc content of autumn tea is in the order of loam soil > clay soil > sandy soil. The zinc content of autumn tea varies between 5.8% and 8.08%.

Table 6. The zinc content of the trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Soil effective zinc mg/kg	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	54.26 ± 4.18	1.45 ± 0.32	1.26 ± 0.00	/	/	/
	Loamy	53.36 ± 0.78	2.21 ± 0.08	1.26 ± 0.05	/	19.26 ± 1.26	/
	Clay	50.63 ± 0.18	3.69 ± 0.05	0.98 ± 0.24	1.36 ± 0.00	20.26 ± 0.15	0.29 ± 0.09
Autumn tea	Sandy soil	23.48 ± 0.56	118.36 ± 0.32	1.25 ± 0.26	/	/	/
	Loamy	37.36 ± 3.54	248.69 ± 10.56	1.48 ± 0.09	/	/	/
	Clay	31.56 ± 1.48	274.56 ± 15.69	2.06 ± 0.18	1.29 ± 0.05	4.26 ± 0.69	0.26 ± 0.09

3.1.7. Boron

Table 7. The boron content of the trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	15.26 ± 1.63	0.41 ± 0.05	/	/	/
	Loamy	15.69 ± 0.49	0.62 ± 0.03	/	76.56 ± 7.95	/
	Clay	15.69 ± 0.98	0.95 ± 0.05	1.26 ± 0.15	72.99 ± 8.36	0.93 ± 0.05
Autumn tea	Sandy soil	19.87 ± 0.96	92.36 ± 3.21	/	/	/
	Loamy	19.87 ± 1.65	157.96 ± 11.29	/	12.56 ± 1.96	/
	Clay	18.59 ± 1.32	162.58 ± 16.69	1.16 ± 0.04	19.15 ± 4.36	0.81 ± 0.04

Table 7 shows the boron content of tea micronutrients in different soil conditions. The agricultural efficiency of boron in spring tea was 0.93 kg and that of boron in autumn tea was 0.81 kg after different soil treatments. The fertilizer utilization rate of boron in spring tea and autumn tea was 1.26% and 1.16%, respectively. The physiological utilization of spring tea boron was 76.56 kg and 72.99 kg and that of autumn tea boron was 12.56 kg and 19.15 kg.

3.1.8. Molybdenum

Table 8 shows the molybdenum content of micronutrients in tea in different soil conditions. The molybdenum agricultural efficiency of spring tea was 2.79 kg after different soil treatments, and the molybdenum agricultural efficiency of spring tea between different soil conditions showed significant differences. The molybdenum agricultural efficiency of autumn tea was 2.59 kg, and the molybdenum agricultural efficiency of autumn tea produced significant differences between different soil conditions.

Table 8. Molybdenum content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	0.19 ± 0.06	2.38 ± 0.26	/	/	/
	Loamy	0.08 ± 0.04	4.34 ± 0.36	/	12.36 ± 1.65	/
	Clay	0.18 ± 0.01	8.15 ± 1.49	0.38 ± 0.12	7.98 ± 2.25	2.79 ± 0.19
Autumn tea	Sandy soil	0.26 ± 0.03	1.28 ± 0.06	/	/	/
	Loamy	0.24 ± 0.06	1.67 ± 0.04	/	1.57 ± 0.26	/
	Clay	0.27 ± 0.06	2.39 ± 0.17	0.398 ± 0.07	1.27 ± 0.06	2.59 ± 0.18

3.1.9. Selenium

Table 9 shows the selenium content of tea trace elements in different soil conditions. After different soil treatments, the selenium content of autumn tea was in the order of loam soil > sandy soil = clay soil. The selenium content of autumn tea was 0.08%, 0.04%, and 0.04%, respectively. The amount of selenium carried over showed that sandy soil > loamy soil > clay soil. The amount of selenium carried over increased by 142.37 kg and 94.97 kg.

Table 9. Selenium content of trace elements of tea in different soil conditions.

Tea season	Soil	Content/%	Carrying capacity kg/acre	Fertilizer utilization/%	Physiological utilization kg/kg	Agricultural efficiency kg/kg
Spring tea	Sandy soil	0.05 ± 0.03	0.87 ± 0.04	/	/	/
	Loamy	0.03 ± 0.04	1.68 ± 0.05	/	25.65 ± 3.78	/
	Clay	0.03 ± 0.04	2.34 ± 0.19	0.09 ± 0.02	29.15 ± 4.48	2.95 ± 0.19
Autumn tea	Sandy soil	0.04 ± 0.01	146.99 ± 4.26	/	/	/
	Loamy	0.08 ± 0.00	289.36 ± 10.36	/	5.18 ± 0.09	/
	Clay	0.04 ± 0.02	384.33 ± 20.96	0.09 ± 0.02	5.69 ± 0.07	2.57 ± 0.19

3.2. Analysis of the effect of micronutrient accumulation in tea on plant antioxidant enzyme activity

3.2.1. Effect of micronutrient accumulation in tea on plant MDA activity

Figure 1 shows the effect of different Mn treatments on the MDA content of tea leaves. Under the same Mn mass fraction treatments, the MDA content was always lower with trace element accumulation than without trace element accumulation. Under the four different mass fraction Mn treatments, the MDA content decreased by 7.69%, 9.83%, 63.33%, and 51.43%. The effect of manganese application on MDA content in tea leaves was complex, and the content decreased first and then increased. Both with and without trace elements, the MDA content of tea leaves was maximum at 1.79 μmol/g. The high content of MDA indicates that the degree of membrane peroxidation of plant cells is high and the cell membrane is seriously damaged.

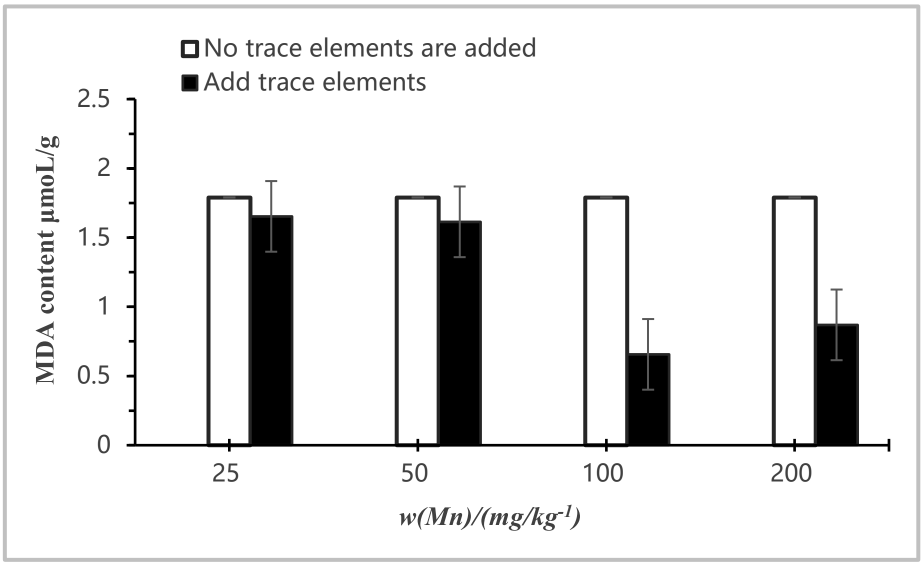

Figure 1. The effect of different MnS on the content of the tea in tea.

3.2.2. Effect of micronutrient accumulation in tea on plant SOD activity

Figure 2 shows the effect of different Mn treatments on the SOD content of tea leaves. The SOD activity of tea leaves without trace elements was significantly lower than that of tea leaves with trace elements under four different mass fractions of Mn treatments. The SOD activity of tea leaves under trace element-free conditions was significantly reduced by 16.00% to 50.77% compared to that of tea leaves with trace elements. Mn treatment is more conducive to enhancing the activity of SOD and pod in tea leaves and reducing the content of MDA in leaves, which is conducive to enhancing the stress resistance and adaptability of tea plants to the outside world in the later growth, and promoting tea to absorb more nutrients in the growth process.

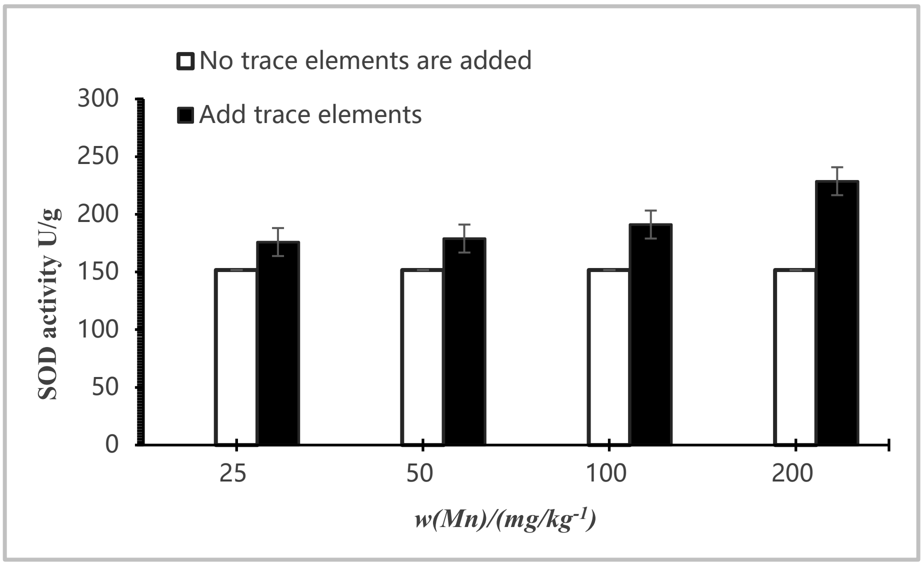

Figure 2. Effects of different MnS on sod content of tea.

3.2.3. Effect of micronutrient accumulation in tea on plant POD activity

Figure 3 shows the effect of different Mn treatments on the POD content of tea leaves, as can be seen from **Figure 3**: With the increase of Mn mass fraction, tea leaf POD activity was significantly increased. Mn treatment of 0–200 mg/kg, the POD activity was realized as: With trace elements > without trace elements, with trace elements tea leaf POD activity decreased by 2.01%–37.5%. At 200 mg/kg Mn treatment, the POD activity of tea leaves with trace elements increased significantly by 29.63% compared with that without trace elements.

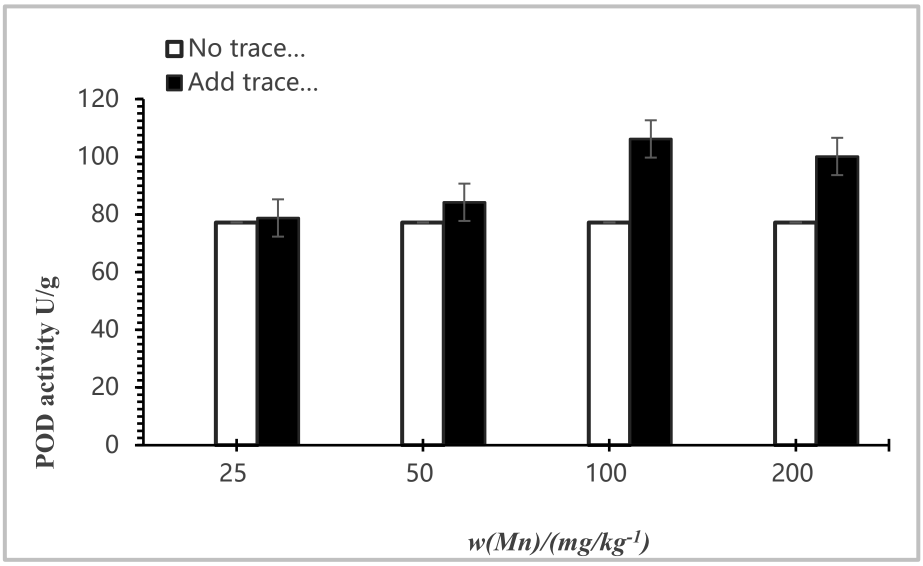

Figure 3. The effect of different MnS on the pod content of tea.

3.2.4. Effect of micronutrient accumulation in tea on plant CAT activity

Figure 4 shows the effect of different Mn treatments on the CAT content of tea leaves, the CAT activity of tea leaves with trace element addition increased by 2.94%, 12.24%, 72.73% and 2.41% respectively compared to those without trace element addition. As the mass fraction of Mn increased, the CAT activity of tea leaves was significantly increased and then decreased. The CAT activities of tea leaves were maximum at 100 mg/kg Mn treatment.

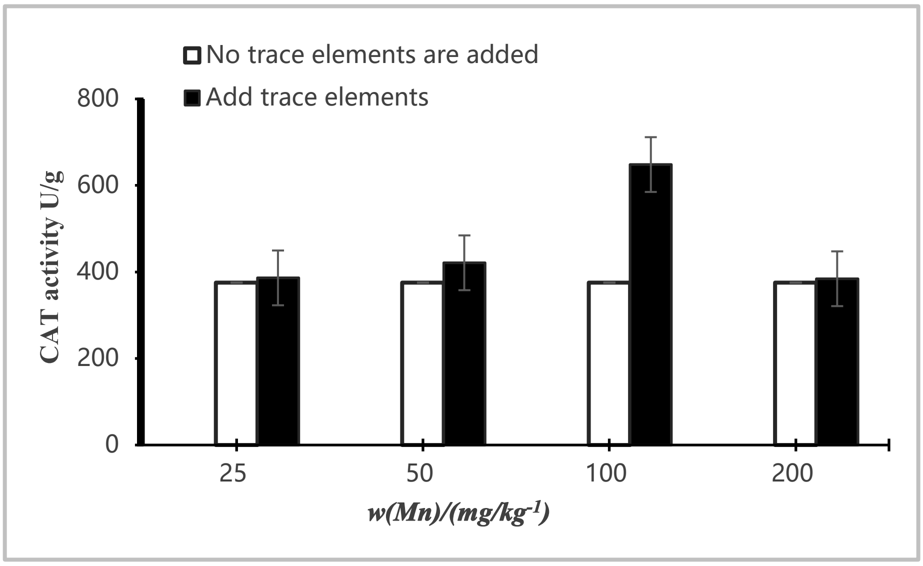

Figure 4. The effects of different MnS on the cat content of tea.

3.2.5. T-AOC activity

Figure 5 shows the effect of different Mn treatments on the total antioxidant activity of tea leaves. With the increase of Mn mass fraction, the T-AOC activity of tea leaves with added trace elements was significantly increased. The T-AOC activity of tea leaves under four different Mn treatments was with trace elements > without trace elements. Compared with the tea leaves without added trace elements, the T-AOC of tea leaves with added trace elements was increased by 18.75%, 14.20%, 28.06%, and 35.14%.

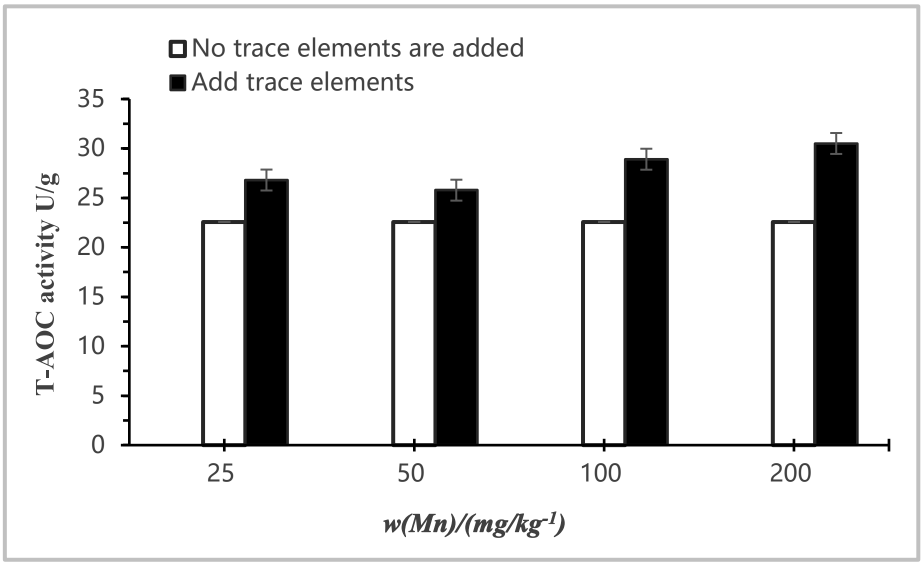

Figure 5. The effect of different MnS on the total antioxidant activity of tea.

4. Conclusion

Tea is a national beverage with a long history and is deeply loved by everyone. It contains a variety of nutrients that are beneficial to the human body. Therefore, tea as a carrier, through fertilizer to convert inorganic zinc, selenium into easily absorbed, low toxicity of organic zinc, selenium, in supplementing the daily human body needs trace elements have certain advantages.

In this paper, the Southern Anhui region of China was used as the soil sample collection site. The soil of tea origins in different ecological environments was collected by using the S-sampling method. The total trace elements and effective state trace elements in tea were determined respectively to assess the effect of trace element accumulation in tea under different conditions. Meanwhile, the results of antioxidant enzyme activities of tea were obtained through different experimental methods.

1) Under different soil conditions, the nitrogen content of spring tea showed clay soil > loamy soil > sandy soil, and the nitrogen content of spring tea increased by 0.74% and 1.3%, and the amount of carry-over showed clay soil > loamy soil > sandy soil, and the amount of carry-over was 1.63%, 2.91%, and 4.98%, respectively. Clay soil in fall tea carried the highest amount of 503.96 kg/mu.
2) The effect of different Mn treatments on MDA activity in tea leaves was analyzed. Under the condition of the same Mn mass fraction, the MDA content was trace element accumulation < no trace element accumulation, and the MDA content was decreased by 7.69%, 9.83%, 63.33%, and 51.43% under the four different mass Mn treatments. Both with and without trace elements, the MDA content of tea leaves was maximum at 1.79 μmol/g. The high content of MDA indicates that the degree of membrane peroxidation of plant cells is high and the cell membrane is seriously damaged.
3) The total antioxidant activity of tea leaves was tested. Compared to tea leaves with added trace elements, the T-AOC of tea leaves without added trace elements was reduced by 18.75%, 14.20%, 28.06%, and 35.14% compared to that of the single crop, and the strongest T-AOC activity was observed at a Mn content of 200 mg/kg.

In summary, the yield and quality of tea with type fertilizer were better than that without type fertilizer, which was related to the nature of fertilizer and nutrient input. The long-term positioning experiment of tea garden found that the yield increase effect of fertilizer treatment was better than that of organic fertilizer treatment at the initial stage of the experiment. With the increase of fertilization years, organic fertilizer mineralization accumulates enough nutrients, and the effect of organic fertilizer can be shown.

Due to the limitations of the researchers' level and the research time frame, the speciation analysis of arsenic, selenium, chromium, and manganese in this study is still inadequate. In the next stage, the structures with unknown morphologies will be identified through ESI-MS and other methods to ascertain their specific forms. Moreover, it will be explored as to how diverse trace elements regulate the activity of antioxidant enzymes within plants. By integrating molecular biology techniques, such as gene expression analysis or metabolite alterations, the mechanism by which trace elements augment antioxidant capacity will be further elucidated.

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