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Assessment of Nutrient Distribution of Tea Garden Soil in Maoshan Tea Production Area of Jiangsu Province China

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***Abstract*: This study investigated the soil nutrient distribution of tea gardens in Maoshan tea production area in Jiangsu province. Soil testing results showed that the nutrition distribution was not consistent across the area. In general, there were sufficient organic matter (OM), nitrogen (N), and potassium (K) in the soil, but not sufficient phosphorous (P) in more than half of the area investigated. The average OM, N, P, and K were 0.45%, 0.39%, 2.03 mg.kg^{-1}, and 0.83 mg.kg^{-1}, respectively. Among other nutrients investigated, zinc (Zn) was sufficient to meet the nutrition demand of tea plants, and magnesium (Mg) and manganese (Mn) were of moderate levels, and 23.18% of the investigated area met the standard of having at least 30 mg.kg^{-1} of sulfur (S) in the soil for highly productive tea gardens.**

***Keywords:* Tea Garden Soil, Nutrition Distribution, Nutrition Assessment, Maoshan, Jiangsu**

I. Introduction

Tea is a traditional crop in Jiangsu Province, where tea gardens are distributed across the south of the province and along the north side of Yangtze River. Tea gardens can also be found along the Huaihe River and along the shore of East Sea in the North-east of Jiangsu Province.

Maoshan mountain area, which is located in South-west of Zhenjiang city Jiangsu province with a history of tea growing more than 2000 years, is now a famous Jiangsu tea industrial belt. The tea product area, consists of the cities of Jurong, Jintan, Lishui, Dantu and Danyang, produces large amounts of quality tea. The climate of this district is mild, having four distinguished seasons, with an average annual temperature of 15.3 °C, annual rainfall of 1018.6 mm, a frost free period of 228 days, and annual average humidity of 78%. Soil types in the area includes yellow earth, yellow-brown earth, yellow-cinnamon soil, brown earth, red earth, lateritic red earth, humid-thermo ferralitic, purplish soil, stanozems, mountain meadow soil, paddy soil etc., which represents major soil types of hills in Jiangsu province(*Weng Zhenpei*, 1959, *Chen xin* et al, 2009). In general, most soils are suitable for tea growing except paddy soil, which was formed by long-term rice farming.

Economic production of tea is dependent on fertilization management of the soil, however soil in tea gardens is often deficient in mineral nutrition for the reason that tea is usually planted in sandy and acid soil in hills and low mountains. Therefore, it is necessary to analyze the soil nutrient status to determine the mineral nutrient deficiencies(Zhou Jun et al 2006; Yang Yajun,2010; *Li Jinghui* et al*, 2012,*) .

The nutrition distribution, status of contaminant, fertilizer efficiency, and soil erosion in tea gardens have been studied in Jiangsu Province(Zhang Yalian et al 2003; Cao Dan et al 2009), yet there has not been a comprehensive analysis on the nutrition distribution. The objective of this study was to analyze the characteristics of nutrition distribution in tea gardens of Jiangsu Province, with the main tea product area Maosahn district as the case.

II. Materials and Methods

Soil sample collection. For a relatively independent growing area, one soil sample was collected on each 4 hm^2 of tea-growing land. Soil, from five sample points, was collected at of 0-20 cm deep and mixed to form one sample. Soil samples consisted of 0.5 kg and were dried at room temperature. A portion of soil (100 g) from each sample was ground through a 20 mesh sieve(1 mm), 50 g of soil from each sample was used for pH analysis. The soil left was further ground pass a 60 mesh sieve (0.25 mm), which was used for nutrient analysis.

Four different tea production regions, Jurongcity, Danyangcity, Zhenjiangcity, Jintan city which surround the Maoshan mountain were selected for the tea garden soil study, in which soil samples (n=220) were collected for basic nutrient analysis with 11 nutrient indexes analyzed per sample.

Besides organic matter(OM), total nitrogen (N) and available phosphorous (P), potassium(K), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), magnesium (Mg), and sulfur (S) were also selected as nutritional indexes of tea garden soil.

Potassium dichromate oxidation method was used to test organic matter. Kjeldahl method was used for total nitrogen analysis. Available mineral elements were extracted with Mehlich 3 universal soil extracting (consisting of 0.2 mol L^{-1} HOAc, 0.25 mol L^{-1} NH_4NO_3, 0.015 mol L^{-1} NH_4F, 0.03 mol L^{-1} HNO_3,0.001 mol L^{-1} EDTA(pH2.5±0.1)), ICP (Inductively Coupled Plasma, Perkin Elemer, USA) was applied to the elements test（*Lu Rukun，2000*）

IBM SPSS Statistics 22.0 (USA) and Excel 2007 (Microsoft,USA) were used for statistical analysis.

III. Results and Discussion

3.1 Soil acid

Table 1. Soil pH classification of samples taken from tea gardens in Maoshan Jiangsu Province, China

pH scope	Sample	Ratio %
≤3.50	1	0.45
3.51-4.00	40	18.2
4.014.50	58	26.4
4.51-5.51	83	37.7
5.51-6.01	22	10
6.01-6.50	8	3.64
6.51-7.00	7	3.18
≥7.01	1	0.45
Max		7.22
Min		3.26
Med		4.6
kurt		0.06
skew		0.72
standard deviation		0.79

According to the results, pH of tea garden soil in this area was between 3.26 and 7.22, with an average pH of 4.74 among all samples, in which 18.53 % of the samples (41 soil samples), had pH lower than 4.00, showing an extreme acidification inclination. Only113 samples (about 50 % of the total samples) had pH between 4.5 and 6.5, which is the optimal pH range for tea production. In general the pH distribution was skewed to the low side, which indicated pH distribution in the area did not fit the normal distribution. A median value, lower than the average, also suggested that there were more samples with lower pH.

3.2 Nutrition distribution

Table 2. Mineral nutrient concentration of soil samples taken from tea gardens in Maoshan, Jiangsu Province, China.

	OM (%)	N (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Fe ($mg.kg^{-1}$)	Mn ($mg.kg^{-1}$)	Mg ($mg.kg^{-1}$)	Zn ($mg.kg^{-1}$)	Cu ($mg.kg^{-1}$)	S ($mg.kg^{-1}$)
Max	3.65	0.313	766.4	872.3	421.7	195.6	919.1	4.83	19.66	799.6
Min	0.01	0.049	0.01	52.53	58.19	9.42	63.46	0.81	1.54	9.78
Med	1.21	0.095	12.2	116.85	173	100.8	317.65	2.25	3.97	39.37
kurt	1.65	4.11	12.34	18.78	0.13	-0.18	0.06	2.68	7.33	157.75
skew	1.12	1.76	3.29	4.08	0.76	-0.28	0.74	1.15	2.38	11.68
STD	0.59	0.41	127.71	124.71	76.78	39.98	175.15	0.7	2.76	55.26
Avg	1.33	0.104	63.09	150.6	187.1	98	350.73	2.27	4.92	46.23
CV	44.54	39.47	202.5	82.82	41.04	40.8	49.94	30.8	56.21	119.54

Note, content of nitrogen-total, other elements-available, STD, standard deviation, CV, coefficient of variance

Table 2 showed that some of the nutrient elements had great variations. For example, the maximum and minimum content of OM, P, K in the test soil can have a difference of hundreds or even thousands times. Soil Mn, Mg and S levels were also great varied across the sampling area. Though the sampled area was limited, P, K distribution fits poorly the normal distribution, and more data lie in the lower side, this hinted that quite a bit of the samples P and K levels may be below the suggested requirement level. Extremely high or extremely low values of N, P, and K existed in the soil samples indicated some of the soil samples had unusually high nutrient levels and some others had unusually low nutrient levels.

3.3 Grade for nutrition

Table 3. Organic matter(OM), total nitrogen (TN), available phosphorous (EP) and available potassium(EK) classification of soil samples from tea gardens in Maoshan Jiangsu Province, China.

OM (%)	SN	Ratio (%)	TN (N, %)	SN	Ratio (%)	EP ($mg· kg^{-1}$)	SN	Ratio (%)	EK ($mg· kg^{-1}$)	SN	Ratio (%)
≤0.01	2	0.91	≤0.050	2	0.91	≤0.0001	36	16.4	≤50.0	0	0
0.47-1.00	70	31.8	0.051-0.075	47	21.4	0.01-1.00	18	8.18	50.1-100	60	27.3
1.01-1.50	76	34.6	0.076-0.100	77	35	1.01-5.00	41	18.6	100.1-200	132	60
1.51-2.00	45	20.5	0.101-0.150	63	28.6	5.01-100	24	10.9	200.1-300	15	6.83
2.01-2.50	15	6.82	0.151-0.200	25	11.4	100.1-500	51	23.2	300.1-400	5	2.27
2.51-3.00	10	4.55	≥0.201	6	2.73	500.1-100	15	6.82	400.1-600	3	1.36
≥3.01	2	0.91				100.1-200	15	6.82	≥600.1	6	2.73
						200.1-300	8	3.64			
						≥300.1	12	5.5			

Note: SN, sample numbers.

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Table 3 gave out the nutrient classification and census of organic matter(OM), total nitrogen (TN), available phosphorous (EP) as well as available potassium(EK) of soil samples from tea gardens in Maoshan area. For OM distribution we can find except for the only 2 samples which contained little OM, most of the soil samples are not insufficient in OM, 67.28% of the investigated samples(148 of 220) had OM of more than 1.00%, which was considered to be necessary for a good tea production system, among them 27 samples had OM of more than 2.00%.

For N distribution analysis in tea gardens of the district, 127 soil samples, that is 57.72% of the total, showed nitrogen content less than 0.1% (Table 3), with 2 samples having total N less than 0.05%, which is considered as the lowest level for a normal productive tea garden. In general, N distribution was in accordance with the distribution of organic matter.

The distribution of P was rather non-uniform compared to that of OM or N, which showed that P content reached as high as above 300 $mg.kg^{-1}$ of soil, and as low as less than 0.0001 $mg.kg^{-1}$ of soil (hardly detectable) in 36 samples (Table 3). 10 $mg.kg^{-1}$ P in soil is the lowest level concentration suggested for tea production systems(*Yang Yajun*,2010)). Of the samples evaluated, 54.09% didn't meet the standard (Table 6), among them 95 samples showed phosphorous content lower than 5.00 $mg.kg^{-1}$ (including 18 samples lower than 1.00 $mg.kg^{-1}$ of soil and 36 samples lower than 0.0001 $mg.kg^{-1}$ of soil).

Table 4 showed in general the soil samples had sufficient K, with 60% of the samples containing available K of 100 $mg.kg^{-1}$-200 $mg.kg^{-1}$. K showed a left-skewed normal distribution, indicating that it still had an inclination to loss and was worthy to notice in case of in-sufficient. Over 60% the investigated soil points had satisfactory level of K considering that available K should be higher than 120 $mg.kg^{-1}$for a high-yield tea garden (*Yang Yajun*, 2010).

Table 4 Classification for zinc , ferrous, copper at al from tea gardens in Maoshan Jiangsu Province, China.

Mg, mg. kg^{-1}	samples numb.	ratio(%)	Zn, mg. kg^{-1}	samples numb.	ratio(%)	Fe, mg. kg^{-1}	samples numb.	ratio(%)
≤100	3	1.36	≤1.00	2	0.91	≤100	28	12.7
100.1-200	40	18.2	1.01-1.50	22	10	100.1-150	57	25.9
200.1-300	59	26.82	1.51-2.00	57	25.9	150.1-200	48	21.8
300.1-400	44	20.02	2.01-2.50	74	33.6	200.1-250	45	20.5
400.1-500	28	12.72	2.51-3.00	38	17.3	250.1-300	22	10
500.1-600	19	8.64	3.01-4.00	21	9.55	300.1-350	13	5.91
≥600.1	27	12.3	≥4.00	6	2.73	≥350.1	7	3.18
Mn, mg·.kg-1	samples numb.	ratio(%)	Cu, mg·.kg-1	samples numb.	ratio (%)	S, mg. kg^{-1}	samples numb.	ratio(%)
≤10.0	2	0.91	≤2.00	3	1.36	≤30	52	23.6
10.1-30.0	20	9.09	2.01-3.00	34	15. 5	30.1-40.0	58	26.4
30.1-50.0	6	2.73	3.01-4.00	74	33.6	40.1-60.1	77	35
50.1-70.0	23	10. 5	4.01-5.00	46	20.9	60.1-80.0	21	9.55
70.1-100	106	482	5.01-8.00	37	16.8	80.1-100.0	5	2.27
100.1-150.0	92	41.8	8.01-10.00	10	4.55	≥100.1	6	2.73

According to the mineral nutrient distribution (Table 4) and nutrient deficiency indexes (Table 5)(*Wu xun ,Ru Guomin* ,1986; *Ruan Jianyun, Wuxun, Shi Yuanzhi* et al,2001), 1.36% of the soil samples were deficient in Mg, 10.00% of the soil samples were deficient in Mn, 10.91% of the samples deficient in Zn, and 23.60% of the sample deficient in S, respectively. No sample was found to contain excessive Cu. Besides, Fe deficiency is usually not a concern in red soil.

Table 5 Indexes of lacking of available mineral elements in fertility tea field(mg kg^{-1})

elements	Mg	Cu	Zn	Mn	S
limit	≥100	≤30	≥1.5	≥30	≥30

IV. Discussion

High yield and senior quality of tea production needs sufficient fertilizer supply as support(Wu xun et al,1986; You Xueqin,2008). Knowing this rule, growers tend to over-fertilize tea gardens, and they often apply manure according to experience instead of utilizing a scientific method based on soil test results(*Han wenyan* ,2002,; *Ma Lifeng*,2013). It was found in this study that nutrition, in small tea production areas we investigated, was extremely heterogeneous. All investigated nutrient indexes varied greatly, which mostly likely resulted from poorly-planned manure application. Though there are scattered hills and mountains in the investigated area, tea gardens are mainly located on flat terrain, with limited elevation of the land. Considering that there are rarely terraced fields in the area, effects of natural factors on the nutritional difference in vertical direction are weak, which further confirms that nutritional difference was mainly attributed to uneven manure application. Therefore, inspection and analysis of nutrition status of tea plantation soil in Maosahn area is necessary.

Like for other crops, OM, along with N, P and K are the most basic and important nutrition for the growth and production of tea plant(*Li Jing* et al,2005; *Tang Jinchi* et al, 2011). OM had a significantly positive correlation to most of the investigated soil nutrient elements, the reason of which could be that organic materials provided considerable amount of N, P, K nutrition (*Li Xueyuan*, 2001). A good soil management program is always associated with balanced supplemental organic fertilizer and chemical fertilizer, consequently the physical-chemical characteristics and ability of the soil to retain nutrition are improved (*Slominski B.A.*,1999; *Liu Sike*, 2007). There was also a positive correlation between available P and K, which may have been affected by the manure application practices rather than being caused directly by soil chemical processes (*Slominski B.A.*,1999; *Pang Feng*, 2009) .

As we have learned, in most cases farmers apply a compound chemic fertilizer of N, P and K, the "three essential factors", at tea gardens in Maoshan district, in which the weight ratio of N, P_2O_5, and K_2O is usually 15%,15%,15% (sometimes 16%,16%,16%) with similar amount of P and K introduced into tea garden soil. However, P in the soil as a fertilizer is easy to be immobilized, which makes it hard to explain the positive correlation between available P and K. On the other hand, rapeseed meal was the major form of organic fertilizer applied, which contains 4.60% -5.24% of N, 2.48% - 3.36% of P_2O_5, and 1.40% -2.86% of K_2O. Ratio of P in rapeseed meal is about 1.5 -2.5 times of that of K. An annual amount of 4000 -6000 kg/hm^2 rapeseed meal was applied to tea gardens as organic fertilizer source and about 600 kg/hm^2 -800 kg/hm^2 of chemical fertilizer was applied. By using rapeseed meal as the organic fertilizer source, much more P than K was introduced to the soil mainly in the form of phytate phosphorus, which releases P slowly and reduces mobilization. This may be the reason why there was a positive relationship between the available P and K(*Liu Sike*,2007; *Sheng Xiuli* et al, 2011). Considering that K may be leached and that the precise amount of the immobilization of P is unpredictable, the use efficiency of applied fertilizers and potential environment hazard need to be further evaluated (*Han Wenyan* et al,1995; *Sheng Xiuli* et al, 2011).

Phosphorus immobilization is a fundamental reason for the lack of available P in acidic soil. The mechanism of P immobilization in the soil has been widely studied, yet how the phosphorus that contained in organic materials, for example in oil seed meal, is transformed into available forms in soil needs to be studied intensively. We found that as many as 54.09% of the inspected points were short of available P (less than 10 mg·kg $^{-1}$) from collected data in this study, which is difficult to explain since many farmers applied meals, which containing enough organic P, as organic matter. Application of oil seed meal annually during autumn or winter has become a routine practice in Jiangsu tea production area. Questions remain as to why so many tea farms were found deficient of available P. Phosphorus in chemical fertilizer can be easily immobilized due to soil acidification, thus it was urgent to know how the organic P was transformed in low pH soil and what fertilizing techniques should be taken(*Han Wenyan* et al,1995; *Utami S.R.*et al,2012)

Zinc is one of the most important micro-elements for the growth of tea plant, which is a constituent of the co-enzyme of many enzymes that play important roles in protein and amino acid synthesis and promotes the formation of catechins and aroma chemicals in tea plants(Wan Xiaochun, 2003,). According to tea research institute of Chinese Academy of Agricultural Sciences (*Ruan Jianyun* et al,2001; *Han Wenyan* et al, 2008), on average there was a total content of Zn of 82.3 mg·.kg-1 - 389.9 mg·.kg-1 in all types of red soils in Hangzhou, with an available content of 1.3 mg.kg^{-1} - 6.1 mg.kg^{-1}. Available Zn in red soil of Jiangxi was of 0.83 mg·.kg^{-1} - 2.2 mg.kg^{-1} (0-15cm deepth). Zinc content in Maoshan was found to be of 0.81 mg.kg^{-1} -4.33 mg·.kg^{-1} in our study with an average content of 2.25 mg.kg^{-1}, which was a little higher than that of Jiangxi and a little lower than that of Hangzhou, representative of the most advanced model of tea garden soil management(*Zhang Yalian* et al,2005; *Alvarez, J. M*. et al,2007). Available Zn concentration of 1.5 mg.kg^{-1} in soil is thought to be the lower limit for a good tea production system(*Wu Xun* et al,1991). In this study, the percentage of investigated points with soil Zn concentration lower than 1.5 mg.kg^{-1} in Maoshan area was 6.36%. In reference to the standard of zinc level in Hangzhou, we concluded that in general tea garden soil in this district can mostly fulfill plant requirement for zinc nutrition, with merely a few points in need of zinc supplement.

Zinc content in soil and its availability to plant roots are affected by many factors, for instance, parent materials of the soil(*Wu Xun* et al,1991). This study has indicated that high level of zinc in parent materials is not always accompanied with high zinc content in soil (Table 10) (*HanWenyan* et al,1995).

Total Zn content in soil did not had a direct correlation with Zn content in parent materials (Table 10). Quantity of zinc released is dependent on the zinc level in cultivated soils, especially those growing perennial crops. Soil nutrient distribution was also affected by the cropping pattern. Rapeseed meal contains 63 mg·.kg-1 of zinc, which may have contributed to most of the zinc in soil of the researched area. It was reported (*Wu Xun* et al,1991; *HanWenyan* et al,1995; *Mukhopadhyay M* .et al, 2013) that available zinc content was between 0.3 mg·.kg-1 and 19.5 mg·.kg-1 in lower-hill red-soil tea gardens across Zhejiang province with most of the samples containing zinc of 0.5 mg.kg^{-1} - 2.6 mg.kg^{-1}. Referred to such data, we can further conclude that zinc distribution in Maoshan tea production area is reasonable and that zinc concentration in the soil is sufficient.

Magnesium is also an important element for tea growth and the formation of chemicals related to tea quality (*Yuko Ishibashi* et al, 2004; *Yao Yuantao* et al, 2009). Zhu and Chen (*Zhu Yongxing* et al,2010) listed available magnesium content in different type of tea garden earths, see table6 .

Table 6 Available magnesium content in different type of tea garden earths

Earths	Brown earth	Yellow–brown earth	Red earth	Lateritic red earth
Mg(mg.kg^{-1})	88.4-215.4	9.2- 316.2	1.8-288.4	3.9-248.0
Mg(Avg, mg.kg^{-1})	125.4	94.2	35.3	22.3

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In general, the average content of available magnesium ranged from22.3 mg.kg-1-125.4 mg.kg-1, based on above scales of magnesium content, the magnesium level in Maoshan, 63.46 mg.kg-1 -919.1 mg.kg-1, is moderate and on the high side.

Manganese is another key element for plant growth and metabolism of tea. From results in this study , available Mn content in Maoshan tea garden was between 9.42 mg.kg-1 and 195.6 mg.kg-1. Ma et al. (*Ma Lifeng* et al, 2006) further separated available manganese into water soluble and exchangeable forms. Water soluble manganese in tea gardens in Zhejiang province ranged from 14.9 - 69.9 mg.kg-1, with an average being 42.4 mg.kg-1, and exchangeable Mn ranged from 8.5 - 98.1 mg.kg-1, with an average of 53.7 mg.kg-1. Mehlich 3 universal soil extractant can extract both water-soluble and exchangeable manganese from the tested soil samples. Our data suggested that tea garden soil in Maoshan area can supply the necessary available manganese for tea production.

Table 7. Manganese content and its releasing strength in red soil tea garden (mg.kg-1)

Sites	Hangzhou Zhejiang			Nanjing Jiangsu		Hefei Anhui		Jurong	Jiangsu		Yixin	Jiangsu	
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
Solution Mn concentration	22.8	58.3	34.8	61.7	47.8	14.9	21.9	20.8	54.6	69.9	50.7	47.4	45.3
Exchangeable Mn	11.6	54.6	29.9	58.3	66.5	118	102	98.1	87.1	13.2	29.9	85	20.1
Available Manganese	34.4	113	64.7	120	114	133	124	119	142	83.1	80.6	132	65.4

Table 7 shows that available Mn levels are sufficient in tea gardens in Zhejiang, Anhui and Jiangsu province(*Xie Zhonglei* et al, 2007, *Ma Lifeng*, 2004). Available Manganese supply should be enough in Maoshan area according to the above results.

Copper is necessary for the growth of tea plant in that it serves as the active center of polyphenol oxdidase which is not only very important in tea plant physiology but also vital for black tea processing and quality mold(Wan Xiaochun, 2003) . Of course too much copper in soil is harmful for tea plants. Usually copper content in tea garden should be lower than 30 mg.kg-1, where Maoshan area has a reasonable copper concentration in the soil (Tables 2 and 8).

Studies were rarely focused on sulfate condition in tea gardens though it plays an important role in the formation of tea aroma, either in the synthesis of aromatic substances in fresh leaves, or in aroma transformation during tea processing(*Han Wenyan* et al, 2003). Nitrogen is often introduced into soil in tea gardens as the form of ammonium sulfate, where the amount sulfur introduced has a positive correlation to nitrogen. Organic fertilizers applied to tea garden through soybean meal or rapeseed meal also contain considerable amount of sulfate, which should have helped to reduce sulfur deficiency in tea garden soils. In a productive tea production system with high yield, available sulfate content is expected to reach 30 mg·.kg-1 or more. By comparison, 23.63% of the inspected points did not meet such standard in our investigation, where the lowest available sulfate content in soil was only 9.78 mg.kg-1. With knowledge of the importance of sulfate in the formation of tea aromatic substance, sulfate migration and transportation in tea garden soil are worthy of further study(*Ye Yong* et al, 1994*; Han Wenyan* et al, 2003).

Many reports showed that there is a relationship between soil nutrients, table8 gave out the nutrition correlation in the investigated area.

Table. 8 Correlation of the nutrition indexes from soil samples from tea gardens in Maoshan Jiangsu Province, China

	pH	OM	N	P	K
pH	1				
OM	-0.2352	1			
N	-0.02734	0.6676**	1		
P	-0.156	0.4373*	0.4654*	1	
K	0.0479	0.3347	0.4525*	0.8518**	1
Fe	0.148	-0.2309	-0.0743	0.1438	0.1148
Mn	0.305	0.0953	0.1843	-0.1026	-0.02883
Mg	0.3198	0.2462	0.2651	-0.4518	-0.2472
Cu	0.192	0.2462	0.3705	0.0896	0.149
Zn	-0.0642	0.6676*	0.0987	0.1857	0.1458
S	-0.1073	0.4373*	0.3736	0.0631	0.1458

Note, content of nitrogen-total, other elements-available
*0.05% level of significant difference, **0.05% level of highly significant difference

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Nutrition analysis data showed that OM had a positive correlation to almost all other indexes except Fe. Correlations between OM and N, OM and P, OM and S were significant, suggesting that OM was one of the most important soil components. We also found that N and P, N and K, P and K were all significantly correlated. Soil pH was positively correlated with available Mn and Mg, but their correlations were not significant. Other indexes investigated had weak correlations with pH. Metallic elements had no correlation with each other, nor with key nutrition components such as OM, N, P, K, except that OM and Zn had a significantly positive correlation. Many researchers indicated acidification can result in the leaching of mineral nutrition in soil, the reason of which is that it is easy for minerals to run off and be permeated into under-ground water under acidic conditions (*Anthi S Bolan* et al, 2013*, Wang Hui* et al, 2010, *Li Lianzhen,* et al,2014*)* However, in our research we did not found any strong or significant correlation between available mineral content and soil pH (Table3). It was suspected that crops are more likely to accumulate heavy metals in acidic soils since solubility of heavy metals was increased, which may further build the risk of food safety (*Jun Qiao* et al,2013, *Cemile Erarslan* et al,2014). Nevertheless further research needs to be conducted to investigate soil solution and leaching and migration of mineral substance in the rhizosphere to confirm such a theory .

There are also other factors like acid rain and chemical fertilizers that impact soil pH. Soil in tea gardens has a tendency of acidification due to the aluminum accumulated and recycled in tea plant(Cao Dan et al,2009,Yang Yajun,2010). Soil pH lower than 4.5 is thought not suitable for growing tea(Yang Yajun, 2010). It is worth noticing in our survey that soil pH lower than 4.5 was common. The influence of soil acidification on the cycling of soil nutrition and on the quantity and quality of tea produced need further intensive study.

We have discussed the distribution characteristics of mineral nutrient in Maoshan tea production areas, with some elements being seriously deficient and other being excessive. Deficient of nutrient will refrain the growing of tea plants, excessive nutrient accompany with leached N and P are often the main pollution sources (*Jun Qiao* et al,2013). Too much of Mn or Mg leached into rivers was reported to cause the water to become discolored (*Donald G*. et al,2014). Over-application of Mn or Mg in tea garden soils need to adjusted. Fertilization practices have great impacts on nutritional and biochemical parameters in soil, and need to be further studied.

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