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HUMIC ACID-BASED TEA SPECIFIC ORGANIC-INORGANIC COMPOUND FERTILIZER PROCESSING AND THEIR APPLICATION

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Abstract

Tea is not only significant traditional advantage industry, but also the main byproduct of agricultural products in China. Though the tea garden area is large in Guizhou province, the yield is very low, this research will be developing a fertilizer for Guizhou tea. The economic benefits, growth data statistics and soil analysis results after fertilization of humic acid-based tea specific organic-inorganic compound fertilizer (HTOF) and WengFu Group's tea specific fertilizer (WGTF) between *Camellia sinensis* cv. Fuding dabaicha and Shiqiantaicha were studied. HTOF was better than WGTF, which improved 5% inorganic nutrients and saved $75.60 -104.79 per hectare of the fertilizer cost every year. One hundred-bud weight of the statistical results showed that applying fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-1 increased by 12.94 g than WGTF, HTOF-2 increased by 13.55 g than WGTF. Applying fertilizers on *Camellia sinensis cv.* Fudingdabaicha after three months, HTOF-1 increased by 2.66 g than WGTF, HTOF-2 increased by 3.15 g than WGTF. In general, the field test results showed that the weathering coal humic acid and humic acid ammonium added in the humic acid-based organic-inorganic compound fertilizer showed the best effect but 100-bud weight statistical results had no significant difference.

Introduction

Fertilizer is one of the most important products of the agrochemical industry, which are added to the soil by releasing necessary nutrients for plant growth (Han *et al*. 2009). Besides, global fertilizer consumption increased by several orders of magnitude over the past 50 years (Khan and Hanjra 2009). Organic-inorganic compound fertilizer contains organic matter and inorganic nutrients material. It is a new type of fertilizer combined with the organic and inorganic fertilizer. Many research results showed that the organic-inorganic compound fertilizer has production effect than chemical fertilizer, and it also improves the utilization rate of nitrogen fertilizer (Liao *et al.* 1995, Li *et al*. 1999, Lang *et al*. 2008, Wang *et al*. 2009, Zhang *et al*. 2009).

Humic acid (HA) is a principal component of humic substances which is the major organic constituents of soil, peat, coal, dystrophic lakes and ocean water. It is produced by biodegradation of dead organic matter and a complex mixture of many different acids containing carboxyl and phenolate groups (Ni *et al.* 2010). There are many different kinds of humic acid fertilizer, such as humic acid ammonium, sodium humate, potassium humate, nitro humic acid, fulvic acid, humic acid compound fertilizer, humic acid liquid fertilizer, humic acid - pesticide fertilizer, etc. As a kind of organic fertilizer, HA can regulate plant growth, accelerate root development, improve soil cluster and benefit the absorption of nutrient elements (Valdrighi *et al.* 1996, Vlcková *et al.* 2009). Humic acid is also an important composition of soil organic matter. If one can came out of the weathered coal humic acid activation and process together with chemical fertilizer and applied to the soil, it can raise the activation of soil, increases the use of fertilizer effect, and improves the quality of the crops (Albert *et al.* 2005). China is rich in coal humic acid resources, which has

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been proven lignite humic acid 126.46 billion tons, weathering coal 100 billion tons, 12.48 billion tons of peat, and these resources are widely distributed, weathering coal reserves are abundant in Guizhou province where humic acid content is higher (Liu *et al*. 2011).

Tea is an important traditional advantage industry in China, and the main export of agricultural products. A field experiment showed that the humic acid fertilizer could improve the yield of fresh tea leaf, and promote bud density and 100-bud weight, at the same time, the application of humic acid fertilizer could improve the tea quality (Peng *et al*. 2012). According to the statistical data of 2012 of national Bureau of Statistics of the People's Republic of China, in Guizhou province tea garden total area was 251,300 ha, fourth of China and the actual tea picking area was 121,300 ha, seventh of China. The tea production was 74400 t, eighth of the country. So calculation showed that the tea yield was 613.36 kg/ha of Guizhou in 2012, 15th of the country. The data that Guizhou province tea garden area is big, but the yield is very low, at the same time there are a lot of tea gardens in juvenile stage. So it will have the important value and meaning of research, if using coal humic acid produce fertilizer and its application in tea plantations.

Materials and Methods

At present, most tea cultivars planted in Guizhou are Fuding Dabai Tea and Shiqianfu Tea, Guizhou soil organ. The reason is that these two tea varieties have strong adaptability and good performance. One bud and two leaves of Fuding great white tea are 5.1 cm long and the weight of 100 buds is 23 grams. Shiqian moss tea is a local variety bred by local tea growers of all nationalities in Shiqian County, Guizhou Province, China. The mother tree belongs to the series of ancient tea trees.

In Guizhou soil, organic matter and total nitrogen content are higher in the overall level, on an average 4.06 and 0.204%. Soil rapidly-available phosphorus content is low, an average of 8.06 mg/kg, rapidly-available potassium average of 124.40 mg/kg, effective trace element such as iron, manganese, copper, zinc, molybdenum, boron, average content were 70.83, 27.40, 2.50, 1.73, 0.174 and 0.38 mg/kg, respectively (Qin *et al*. 2009). According to tea growing area of Guizhou province, the condition such as temperature, rainfall, soil and farmers conventionally grown application experience, design the humic acid-based tea specific organic-inorganic compound fertilizer (HTOF) nutrients ratio of $N : P_2O_5 : K_2O = 13 : 7 : 5$, OM $\geq$ 15% (Table 1). At the same time, because of the different humic acid raw material prices and humic acid content is different, so from the aspects of production cost and the nutrient content for different types of humic acid products designed different kinds to add the test (Table 2).

Organic fertilizer 385 kg, urea 226 kg, diammonium phosphate 156 kg and potassium sulphate 100 kg, all materials were crusted at 60 mesh. Hundred mesh sieve of bentonite 60 and 20 kg of calcium sulphate as solid adhesive were taken. Different humic acid powder 50 kg. Borax 2 kg and 0.5 kg manganese sulfate and 0.5 kg zinc sulfate as nutritional additives. Water was used as liquid adhesive.

Firstly, organic fertilizer and inorganic fertilizer were crushed. Secondly, according to take the organic fertilizer powder, inorganic fertilizer powder, humic acid powder, nutritional additives and solid adhesive, and then all materials were mixed. When the mixing process, the right amount of water wet mixed material were used. The mixed material are used squeezing granulator granulation. Finally, were sieved the granulation fertilizer particles into fertilizer particle size of 3 - 5 mm, with moisture proof materials for packaged, which is HTOF. The specific process as shown is Fig. 1.

The field experiments in young tea plants of HTOF were carried out in Jiu’an Township, Huaxi district, Guiyang city, Guizhou province. Jiu’an Township is located in 106°31' E, 30°29' N,

between 1090 - 1402 meters above sea level, and is a subtropical monsoon climate moist area. Experiments were set up in nine processing groups and used the WengFu Group's tea specific fertilizer (WGTF) (N: P_2O_5 : K_2O=11 : 5 : 4, OM ≥ 20%) as a control processing. Each processing repeated three times. The area of every experimental plot was 25 m^2. Fertilizer applied in two years of *Camellia sinensis cv.* Shiqiantaicha and *Camellia sinensis cv.* Fudingdabaicha. The HTOFs (HTOF-0-HTOF-6) were used 1124.5 g in every experimental plot and the WGTF was used 1405.5 g in every experimental plot.

Table 1. The ratio of material of HTOF.

Fertilizer material	Proportion (%)	Producing one ton of dosage (kg)
Urea	22.60	226
Diammonium phosphate	15.60	156
Potassium sulfate	10.00	100
Organic fertilizer	38.50	385
Borax	0.20	2
Zinc sulfate	0.05	0.5
Manganese sulfate	0.05	0.5
Bentonite	6.00	60
Calcium sulphate	2.00	20
Humic acid	5.00	50

Table 2. Adding humic acid species of HTOF.

Different processing	Adding humic acid species
HTOF-0	5% Bentonite
HTOF-1	Weathering coal humic acid
HTOF-2	Humic acid ammonium
HTOF-3	Potassium humate
HTOF-4	Humic acid ammonium: Potassium humate = 2.5 : 2.5
HTOF-5	Humic acid ammonium: Potassium humate = 1 : 4
HTOF-6	Humic acid ammonium: Potassium humate = 4 : 1

After three months of fertilization 100-bud weight, bud density, plant height, number of new leaves and leaf area of each treatment group were measured (Li 2010, Song 2011, Zhong 2013).

In each processing random sampling was done and average of three samples were taken. Within the groups randomly placed three bud density in investigation box, box covered an area of 0.15 m^2, statistics of bud in the frame number, three times the average of the results, namely density for this handling of bud.

The plant height of randomly selected 5 plant was recorded from the base to the top of plant by using a measuring tape and the average value was taken. Randomly selected 30 branches with new leaves were counted and then the average number of new leaves were recorded

Selected 20 new tips within a bud with three leaves, took the new tip on the base of the second leaf for the determination of object, its leaf length and width, with the average leaf area coefficient method, the leaf area = leaf length × leaf width × 0.7 were measured

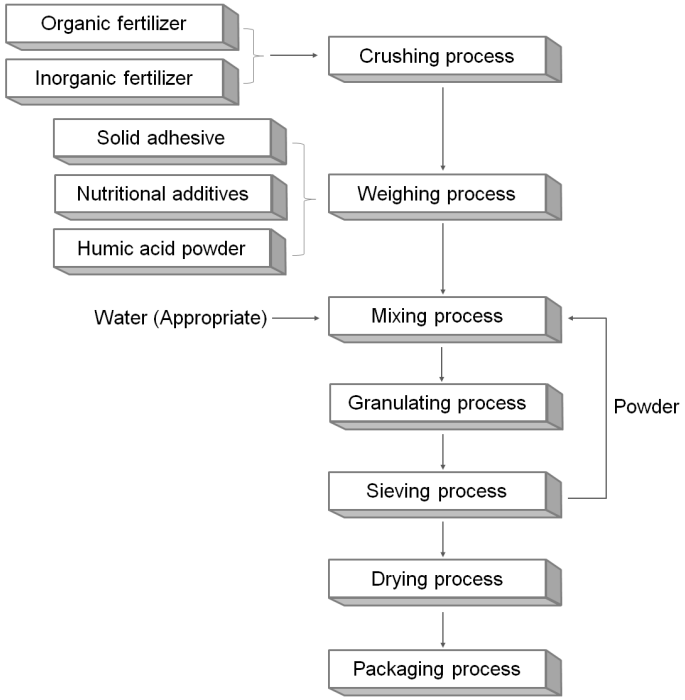

Fig. 1. Process flow chart of the HTOF processing operation.

The soil samples were collect from each treatment group for laboratory analyses. After air-drying and homogenization, soil samples were passed through a 2 stainless sieve before the determination of the basic physico-chemical soil characteristics. The pH and EC were measured directly. Ammonium nitrogen, available phosphorus and rapidly available potassium were determined by spectrophotometer. Determination of available phosphorus was in 685 nm wavelength by spectrophotometer in 420, 685 and 685 nm wavelength, respectively.

Results and Discussion

The nutrient content of HTOF is N : P_2O_5 : K_2O = 13 : 7 : 5, while the nutrient content of WGTF is N : P_2O_5 : K_2O = 11 : 5 : 4, HTOF improves 5% inorganic nutrients. If cost the same nutrient content in the same agricultural production, the HTOF will be saved $75.60 - 104.79 per hectare of the fertilizer cost each year than the WGTF. The cost calculation results are shown in Table 3. Considering the cost of production, adding humic acid powder is the most economical choice.

One hundred-bud weight of the statistical results showed that applying fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-1 increased by 12.94 g than WGTF, HTOF-2 increased by 13.55 g than WGTF. Applying fertilizers on *Camellia sinensis* cv. Fudingdabaicha after three months, HTOF-1 increased by 2.66 g than WGTF, HTOF-2 increased by 3.15 g than WGTF. The results also showed that after applying HTOF-1, HTOF-2 and the application of WGTF have a significant difference. Bud density of the statistical results showed that applying fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-6 increased by 10.11 buds than WGTF. Applying fertilizers on *Camellia sinensis* cv. Fudingdabaicha after three months,

HTOF-1 increased by 16.66 buds than WGTF. Plant height of the statistical results showed that applying fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-2 increased by 6.13 cm than WGTF. The results also showed that after applying HTOF-2 and the application of WGTF exist significant difference. Applying fertilizers on *Camellia sinensis* cv. Fudingdabaicha after three months, HTOF-1 increased by 7.93 cm than WGTF. The results also showed that after applying HTOF-1 and the application of WGTF exist significant difference. In general, the field test results found that the weathering coal humic acid and humic acid ammonium were added in the humic acid-based organic-inorganic compound fertilizer showed the best effect, but 100-bud weight statistical results showed no significant difference. The different growth data statistics after fertilization in Tables 4 and 5. Guizhou soil was phosphorus deficiency and enrichment in potassium, adding potassium humate is neither economic nor practical. Tea as a leaf crop, demand for nitrogen is very urgent. It can absorb the ammonium nitrogen and nitrate nitrogen. In contrast, tea particularly preferred to ammonium nitrogen. So adding humic acid ammonium is a good choice.

Table 3. The economic benefits of fertilizers.

Different processing	Adding humic acid species	Dosage (kg·y·ha)	Production cost ($/t)	Price ($/t)	Cost ($·y·ha)
CK	-	-	-	-	-
HTOF-0	5% bentonite	1500	265.14	273.21	409.80
HTOF-1	Weathering coal humic acid	1500	266.76	274.83	412.20
HTOF-2	Humic acid ammonium	1500	272.41	280.48	420.75
HTOF-3	Potassium humate	1500	284.51	292.58	438.90
HTOF-4	Humic acid ammonium: Potassium humate = 2.5 : 2.5	1500	278.46	286.53	429.75
HTOF-5	Humic acid ammonium: Potassium humate = 1 : 4	1500	282.09	290.16	435.30
HTOF-6	Humic acid ammonium: Potassium humate = 4 : 1	1500	274.83	282.90	424.35
WGTF	-	1875	-	274.38	514.50

The results showed that the soil pH did not change significantly before and after fertilization. It means short-term fertilization measures on soil pH effects is not obvious. The determination results of EC showed that before fertilization significantly higher than after fertilization. The *Camellia sinensis* cv. Shiqiantaicha and *Camellia sinensis* cv. Fudingdabaicha showed the same results. The analysis of ammonium nitrogen showed that applying fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-1 increased by 8.29 mg/g than WGTF. The available phosphorus of the analysis results shows that applying fertilizers on *Camellia sinensis* cv. Fudingdabaicha after three months, HTOF-1 increased by 1.67 mg/g than WGTF, HTOF-2 increased by 3.95 mg/g than WGTF. The rapidly-available potassium of the analysis results showed that applying fertilizers on *Camellia sinensis cv.* Shiqiantaicha after three months, HTOF-2 increased by 9.67 mg/g than WGTF. Applying fertilizers on *Camellia sinensis cv.* Fudingdabaicha after three months, HTOF-1 increased by 44.5 mg/g than WGTF. The different soil analysis results after fertilization are presented in Tables 6 and 7.

Table 4. Different growth data statistics after fertilization of *Camellia sinensis* cv. Shiqiantaicha.

Different processing	100-bud weight (g)	Bud density	Plant height (cm)	Leaf area (cm^2)	Number of new leaves
CK	66.20 ± 0.73 a	40.11 ± 5.04 a	70.00 ± 5.00 a	3.62 ± 1.69 a	6.37 ± 1.61 a
HTOF-0	66.84 ± 0.96 a	43.67 ± 8.54 ab	71.93 ± 4.01 ab	3.99 ± 1.52 a	7.63 ± 1.71 bc
HTOF-1	80.79 ± 2.78 e	52.56 ± 15.18 bc	75.20 ± 5.98 bc	4.40 ± 2.00 a	6.90 ± 0.96 ab
HTOF-2	81.40 ± 1.36 e	51.33 ± 7.35 bc	79.60 ± 4.19 d	4.37 ± 1.73 a	7.37 ± 1.52 bc
HTOF-3	74.17 ± 0.76 cd	50.89 ± 6.01 bc	75.27 ± 3.65 bc	4.21 ± 3.31 a	7.90 ± 1.30 c
HTOF-4	75.77 ± 0.39 d	53.89 ± 10.22 cd	73.53 ± 6.79 abc	4.25 ± 1.78 a	7.53 ± 1.57 bc
HTOF-5	72.62 ± 0.20 c	53.89 ± 7.82 cd	77.20 ± 6.61 cd	4.23 ± 1.87 a	7.70 ± 1.60 bc
HTOF-6	70.25 ± 0.09 b	61.89 ± 10.35 d	75.40 ± 5.63 bc	4.19 ± 3.14 a	6.93 ± 1.53 ab
WGTF	67.85 ± 1.16 a	51.78 ± 6.08 bc	73.47 ± 5.38 abc	4.07 ± 2.82 a	7.23 ± 1.72 bc

*The data are statistical results average ± Sd. Different letters following data within the same column indicate significant differences at $p < 5\%$.

Table 5. Different growth data statistics after fertilization of *Camellia sinensis* cv. Fudingdabaicha.

Different processing	100-bud weight (g)	Bud density	Plant height (cm)	Leaf area (cm^2)	Number of new leaves
CK	42.83 ± 0.05 a	35.89 ± 4.31 a	43.20 ± 3.88 a	4.81 ± 2.20 a	6.23 ± 1.41 a
HTOF-0	51.24 ± 0.32 b	50.56 ± 17.15 b	43.40 ± 3.83 a	4.96 ± 2.33 a	7.27 ± 1.57 b
HTOF-1	56.14 ± 0.66 d	66.22 ± 13.00 c	51.53 ± 4.47 c	5.82 ± 2.69 a	8.20 ± 1.32 c
HTOF-2	56.63 ± 0.53 d	62.56 ± 15.31 bc	45.00 ± 3.16 ab	5.88 ± 1.99 a	7.67 ± 1.73 bc
HTOF-3	54.45 ± 0.39 c	61.44 ± 18.49 bc	45.47 ± 4.03 ab	5.71 ± 2.57 a	7.83 ± 1.60 bc
HTOF-4	53.91 ± 0.21 c	61.22 ± 9.35 bc	43.93 ± 5.12 a	5.79 ± 2.02 a	7.07 ± 1.64 b
HTOF-5	53.58 ± 0.99 c	53.22 ± 12.54 bc	44.00 ± 3.40 a	5.55 ± 2.07 a	7.17 ± 1.68 b
HTOF-6	53.62 ± 0.94 c	60.78 ± 17.35 bc	47.20 ± 3.75 b	5.69 ± 2.24 a	7.53 ± 1.41 bc
WGTF	53.48 ± 0.47 c	49.56 ± 9.77 b	43.60 ± 3.14 a	5.34 ± 1.59 a	7.60 ± 1.59 bc

*The data are statistical results average ± Sd. Different letters following data within the same column indicate significant differences at $p < 5\%$.

Organic-inorganic compound fertilizer combined the characteristics of organic fertilizer and inorganic fertilizer, and reflected the combination of organic and inorganic interaction. The organic fertilizer component of organic-inorganic compound fertilizer provided limited amounts of nutrients, and is more organic form, supply nutrients slowly. The chemical fertilizer component of organic-inorganic compound fertilizer is the main source of nutrient, supply directly to the crops. If more chemical fertilizers is added in organic-inorganic compound fertilizer, then can supply plant more available nutrients, and plants will grow faster. The HTOF improves 5% inorganic nutrients and saved $75.60 - 104.79 per hectare of the fertilizer cost every year than the WGTF. Its machining process is simple and can be used for mass production. HA can regulate plant growth, accelerate root development, improve soil cluster and benefit the absorption of nutrient elements.

When the nitrogen is present in many form (ammonium nitrogen, nitrate nitrogen or organic nitrogen), tea is always preferred ammonium nitrogen. The field test results also showed that the weathering coal humic acid and humic acid ammonium are added in the humic acid-based organic-inorganic compound fertilizer showed the best effect, and 100-bud weight statistical results showed no significant difference. Considering the cost of production and the application effect, adding the weathering coal humic acid and humic acid ammonium may be a good choice. In a word, the weathering coal humic acid and humic acid ammonium are added in the humic acid-based organic-inorganic compound fertilizer, the result of the present study revealed that the applied method can not only save the production cost, reduce manual labor costs, and also improved the 100-bud weight and plant height.

Table 6. different soil analysis results after fertilization of *Camellia sinensis* cv. shiqiantaicha.

Different processing	pH (H_2O)	EC (μs/cm)	NH_4^+ -N (mg/g)	A-P (mg/g)	A-K (mg/g)
Before fertilization	4.77	99.25	29.85	10.77	59.05
CK	4.71	77.35	26.97	1.28	46.98
HTOF-0	4.82	67.15	28.49	7.95	28.97
HTOF-1	4.81	79.50	32.52	3.17	29.57
HTOF-2	4.73	72.40	28.05	2.89	41.04
HTOF-3	4.77	77.05	26.67	3.40	43.65
HTOF-4	4.82	66.15	26.95	2.44	32.26
HTOF-5	4.73	72.85	26.65	5.07	52.93
HTOF-6	4.76	66.75	23.05	7.54	66.65
WGTF	4.73	70.90	24.23	3.57	31.37

Table 7. different soil analysis results after fertilization of *Camellia sinensis* cv. Fudingdabaicha.

Different processing	pH (H_2 O)	EC (μs/cm)	NH_4^+ -N (mg/g)	A-P (mg/g)	A-K (mg/g)
Before fertilization	4.40	86.60	44.78	2.64	86.33
CK	4.61	50.20	17.17	1.98	41.39
HTOF-0	4.46	54.50	19.02	1.86	28.24
HTOF-1	4.42	62.05	19.32	4.06	62.07
HTOF-2	4.44	59.80	18.18	6.34	16.11
HTOF-3	4.52	64.65	19.90	6.83	47.54
HTOF-4	4.46	64.00	26.17	4.80	22.53
HTOF-5	4.42	69.45	26.73	4.09	93.93
HTOF-6	4.49	58.65	19.24	2.02	41.80
WGTF	4.39	65.85	19.15	2.39	17.57

Humic acid is an important composition of soil organic matter. The humic acid-based tea specific organic-inorganic compound fertilizer is better than the WengFu Group's tea specific fertilizer, which improves 5% inorganic nutrients and saves $75.60 - 104.79 per hectare of the fertilizer cost every year. hunered-bud weight of the statistical results showed that applying

fertilizers on *Camellia sinensis* cv. Shiqiantaicha after three months, HTOF-1 increased by 12.94 g than WGTF, HTOF-2 increased by 13.55 g than WGTF. Applying fertilizers on *Camellia sinensis* cv. Fudingdabaicha after three months, HTOF-1 increased by 2.66 g than WGTF, HTOF-2 increased by 3.15 g than WGTF. In general, the field test results showed that the weathering coal humic acid and humic acid ammonium are added in the humic acid-based organic-inorganic compound fertilizer which showed that the best effect, but 100-bud weight statistical results had no significant difference.

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