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Research Article

Determination of Trace Elements in *Corydalis conspersa* and *Corydalis linarioides* by ICP-AES

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In order to establish a method for the simultaneous determination of trace elements Al, As, B, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, P, Si, Ti, and Zn in *Corydalis conspersa and Corydalis linarioides,* we collected the samples from different areas and treated with acid hydrolysis into tissues to be detected by the way of inductively coupled plasma-atomic emission spectrometry compared with the standard element control method. We can know that the contents of Al, Ca, Fe, K, Mg, Na, and P in roots, stems, leaves, and flowers were higher. The contents of elements in different tissues and areas were as follows: flower > leaf > stem > root, Zeku County > Guide County > Nangqian County > Henan County. Among them, the contents of each element in the flowers of Maixiu Forest Farm were higher, while the contents of B, Cr, Cu, Li, Mn, Ni, Si, Ti, and Zn in roots, stems, and leaves of other areas were lower. The contents of heavy metal elements complied with the limit degree. A 3-factor model was obtained by principal component analysis which could clarify 82.46% of the total experimental data; the factors of Al, Fe, Mg, Na, P, Ca, Cu, Si, and Zn had great influence on the efficacy of 21 kinds of medicinal materials. Cluster analysis classified the samples into three categories; the flowers of *Corydalis conspersa* and stems of *Corydalis linarioides* from different collection areas are clustered containing high contents of type 1 and 3 characteristic components; the roots, stems, and leaves from other collection areas are clustered with low contents of 1 and 2 characteristic components. It can be used for the determination of trace elements in *Corydalis conspersa* and *Corydalis linarioides* to provide effective basis for revealing the function of trace elements with plant growth.

1. Introduction

Corydalis conspersa and *Corydalis linarioides* are both *Corydalis* plants belonging to Papaveraceae Family. They are distributed in the Provinces of Shanxi, Gansu, Ningxia, Qinghai, Sichuan, and Tibet Prefecture [1]. They were found under forests, forest margins, shrubs, grass slopes, or crevices at an altitude of 2100–4000 meters. *Corydalis conspersa* was first published in the list of Tibetan plants, and it is called Gandong Ouru in Tibet. It is bitter, astringent, and cold in nature. It has small poison and enters the lung and spleen organs. It has the effect of clearing away heat and detoxification, killing insects, and relieving itching. It is used for sore poison, snake bite, intractable diseases, psoriasis,

scabies, etc. [2]. *Corydalis linarioides* is a famous medicine in Taibai Mountain and Tibetan medicine in Qinghai Province, while the Tibetan medicine is called Jiadaseva [3].

There have the organic chemical components and inorganic chemical elements in the traditional Chinese medicine. In 1869, Russian scientist Dmitri Mendeleev created the periodic table of elements. Up to now, there are 118 kinds of chemical elements. The trace elements in the study include 13 metal elements Al, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Ti, and Zn and 4 nonmetallic elements As, B, P, and Si. Chemical elements have their own physical and chemical properties which play an important physiological role in plants and have a close relationship between the nature, taste, efficacy, and Traditional Chinese Medicine. Therefore, the study of chemical elements in different collection areas and tissues of *Corydalis conspersa* and *Corydalis linarioides* can be used as an important index material basis for distinguishing the quality of medicinal materials and exploring the mechanism of curative effect related to chemical elements.

The main methods for the determination of elements in Chinese medicinal materials are colorimetry [4–6], AAS [7], atomic fluorescence spectrometry [8], inductively coupled plasma-atomic emission spectrometry (ICP-OES/AES) [9, 10], and inductively coupled plasma mass spectrometry (ICP-MS) [11]. The plasma can reach a very high temperature by the ICP-AES, which is conducive to the atoms or ions in the elements to emit photons of characteristic wavelengths decomposed into monochromatic spectra representing each element through the grating spectroscopic system. These spectral energies are detected by the semiconductor detector, and the content of the elements to be measured in the test solution is compared to the standard solution. It has the advantages of high sensitivity, low detection limit, and wide test range to simultaneously determine the multiple elements.

The content of trace elements in *Corydalis conspersa* and *Corydalis linarioides* was determined by ICP-AES to provide a certain scientific basis for the further researches regarding the meaningful functions of the elements within the plant tissues and metabolism of plant growth.

2. Materials and Methods

2.1. Collection and Treatment of Drug. The medicinal materials were collected in Hainan, Huangnan, Yushu, and Haibei Tibetan Autonomous Prefecture of Qinghai Province in August 2017. After identification by Professor Lin Pengcheng (Qinghai Nationalities University), the authors compared the specimens with the China and Qinghai flora to identify them as *Corydalis conspersa* and *Corydalis linarioides*.

After cleaning the fresh plants, they were divided into dried roots, stems, leaves, and flowers in the shade and crushed using a 80-mesh sieve (Table 1 and Figure 1).

2.2. Reference and Reagent Materials. Single element standard solution (National Institute of Nonferrous Metals, Tanmo Quality Control Standard Material Center, concentration of 1000 μg/ml) (Table 2), concentrated hydrochloric acid, concentrated nitric acid (Tianjin Bodi Chemical Co., Ltd. and Jiangyin Runma Electronic Materials Co., Ltd., electronic grade), microporous membrane (0.45 μm, Tianjin Jinteng Experimental Equipment Co., Ltd.), and purified water (Asia silicon industry) (self-made by limited liability company) were purchased.

2.3. Instruments. Inductively coupled plasma-atomic emission spectrometer (Thermo Fisher Technology Co., Ltd., model 6300), pure water treatment system (Asia Silicon Co., Ltd.), BP211D electronic balance (Sartorius company, Germany), Micropipette (Dragon lab), and Automatic sampler (CETAC asx-520x) were used.

2.4. Working Parameters of the Instrument. The working parameters of the instrument are listed in Table 3.

2.5. Selection of Analysis Line. According to the principles of low detection limit, high sensitivity, less interference of coexisting elements, and low spectral interference, the following analytical lines (nm) were selected for analysis [12]: Al, 396.152; As, 197.262; B, 208.959; Ca, 317.033; Cr, 267.716; Cu, 324.754; Fe, 259.940; K, 766.490; Li, 460.286; Mg, 270.553; Mn, 257.610; Na, 589.592; Ni, 231.604; P, 177.495; Si, 251.611; Ti, 334.941; and Zn, 231.856.

2.6. Preparation of Solutions

2.6.1. Preparation of Single Reference Solution. The concentration of single standard solution of Al, As, B, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, P, Si, Ti, and Zn is 1000 μg/ml.

2.6.2. Preparation of Mixed Reference Solution. Accurately suck 5.0 ml of each element standard solution in Table 2, put it into a 500.0 ml volumetric flask, and fix the volume with 5% HNO_3 to prepare 10 μg/ml element mixed standard solution; accurately absorb 10 μg/ml element mixed standard solution with appropriate amount of 1.0, 10.0, 20.0, 30.0, 40.0, and 50.0 ml, put into a 100.0 ml volumetric flask, and fix the volume of 5% HNO_3 to prepare 0.1, 1.0, 2.0, 3.0, 4.0, and 5.0 μg/ml, respectively, and 10.0 μg/ml of mixed standard solution.

2.6.3. Preparation of Test Solution. Accurately weigh 0.2 g (0.01-0.02 g for flower) of *Corydalis conspersa* and *Corydalis linarioides*, put them into a conical flask with stopper, add 15.0 ml HNO_3: HCl (3 : 1) mixed acid solution in the fume hood, shake well, and dissolve; close the plug and soak in the fume hood overnight. The acid solution in the fume hood was heated and digested on an electric furnace for 30 min-2 h until dried; 4.0 ml HNO_3: HCl (3 : 1) mixed acid solution was added to each sample, and then the mixture was shaken and digested overnight. After overnight, the acid solution is heated and digested in an electric furnace and kept boiling for 30 min-2 h on the condition of fume hood. After the

Table 1: Specific information of collected samples from *Corydalis conspersa* and *Corydalis linarioides*.

No.	Code	Origin	Place	Tissue
1	BHHJ-LJS-R	County of Guide from Hainan Zhou	La Ji Mountain	Root
2	BHHJ-LJS-S			Stem
3	BHHJ-LJS-L			Leaf
4	BHHJ-LJS-F			Flower
5	BHHJ-NQ-R	County of Zhao Xiao from Yushu Zhou	Xiang Longxiagu Mountain	Root
6	BHHJ-NQ-S			Stem
7	BHHJ-NQ-L			Leaf
8	BHHJ-NQ-F			Flower
9	BHHJ-MXLC-R	County of Zeku from Huangnan Zhou	Maixiu Linchang	Root
10	BHHJ-MXLC-S			Stem
11	BHHJ-MXLC-L			Leaf
12	BHHJ-MXLC-F			Flower
13	BHHJ-JGS-R	Tuo Yemaxiang from Huangnan Zhou	Ji Gang Mountain	Root
14	BHHJ-JGS-S			Stem
15	BHHJ-JGS-L			Leaf
16	BHHJ-JGS-F			Flower
17	BHHJ-QL-R	County of Qilian from Haibei Zhou	Qilian Mountain	Root
18	BHHJ-QL-S			Stem
19	BHHJ-QL-L			Leaf
20	TLHJ-JGS-R	Tuo Yemaxiang from Huangnan Zhou	Ji Gang Mountain	Root
21	TLHJ-JGS-S			Stem

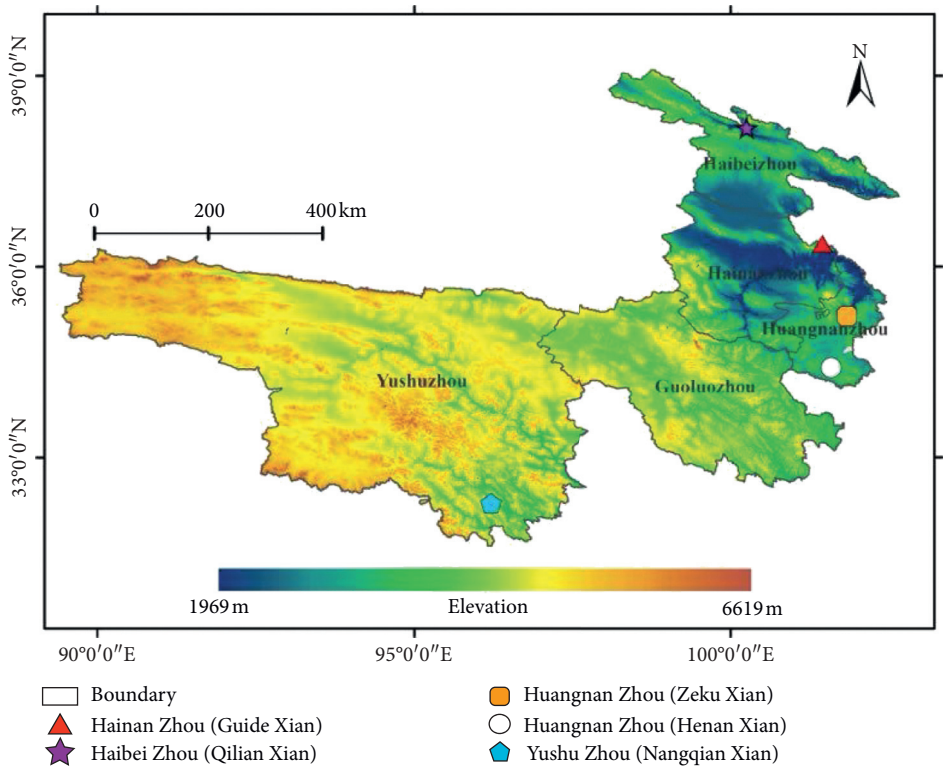

Figure 1: Areas of sample collecting.

Table 2: Information of single element standard solution.

Name of element	No. of national standard	Batch number
Al	BW30019-1000-NC-50	B1908104
As	GSB04-1714-2004	184020-4
B	GSB04-1716-2004	187052-1
Ca	GSB04-1720-2004	18C011-3
Cr	GSB04-1723-2004 (a)	188016-4
Cu	GSB04-1725-2004	18C039-2
Fe	GBW (E) 083185	B1908003
K	GSB04-1733-2004	1870430-3
Li	GSB04-1734-2004	18B041-2
Mg	GSB04-1735-2004	184043-3
Mn	GSB04-1736-2004	17A011-1
Na	GSB04-1738-2004	187025-4
Ni	GSB04-1740-2004	187042-2
P	GSB04-1741-2004 (a)	191065-1
Si	GSB04-1752-2004 (a)	184043
Ti	GSB04-1757-2004	187022
Zn	GSB04-1761-2004	18B027-1

Table 3: Working parameters of ICP-AES instrument.

ICP-AES working parameters	Values
RF power	1150 W
Generator temperature	26°C
Pump speed	25 rpm
Photo temperature	−46.21°C
Auxiliary gas flow	0.5 L/min
Light chamber temperature	37.9°C
Flushing pump speed	100 rpm
Analysis of pump speed	25 rpm
Plasma stabilization time	10 min

white smoke is exhausted, the acid is evaporated until cooled. Then, each sample is diluted with 5% HCl solution into a 100.0 ml volumetric flask and placed overnight. 0.45 μm aqueous-phase microporous filter membrane is used to filter into a 50.0 ml plastic quantitative tube and then put into the refrigerator for freezing. At the same time, 5% HCl and 5% HNO_3 were used as blank control solution [13].

2.7. Development and Validation of Method. The method for detection, separation, and quantitation of the three copies samples was developed and combined the conditions with reference. The validation parameters investigated included linearity and its range, limits of detection and quantitation, precision, stability, repeatability, and recovery.

2.7.1. Study of Linear Relationship and Limits of Detection and Quantitation. Under the working conditions of ICP-AES, the mixed standard solution of 0.1, 1.0, 2.0, 3.0, 4.0, 5.0, and 10.0 μg/ml was determined and the standard curve was drawn with the concentration as the abscissa and the average value of the three intensity measurements as the ordinate. The limits of detection and quantitation were calculated by dividing the 3 and 10 times standard deviation of the measured value from the blank control solution by the slope of the corresponding element standard curve, respectively.

2.7.2. Precision Experiment. Precisely, the same sample solution is drawn for injection, and each sample is detected for 6 times.

2.7.3. Stability Experiment. The same sample solution was precisely absorbed, and the contents of 17 elements were determined at 0.0, 3.0, and 24.0 h after preparation under the determination conditions.

2.7.4. Repeatability Experiment. Around 0.2 g of 5 copies of *Corydalis conspersa* powder was accurately weighed. The samples were prepared according to the way of test solution preparation, and the RSD values of various elements in the samples were determined.

2.7.5. Recovery Experiment. Accurately weigh 6 copies of *Corydalis* powder with known content. The samples were prepared according to the way of test solution preparation and filtered with 0.45 μm microporous membrane, taking 10.0 ml of test solution, adding 1.0 ppm and 10.0 ppm of element mixed standard solution 10.0 ml, respectively, three copies of each concentration, fixing the volume to 50 ml with 5% hydrochloric acid, and mixed well to be detected according to ICP-AES conditions.

3. Results and Discussion

3.1. Methodology Validation

3.1.1. Linear Relationship and Limit. The regression equation of trace elements has a good linear relationship with $R \geq 0.9996$. The detection limits were between 0.0001 μg/g and 0.1024 μg/g. The quantitation limits were between 0.0003 μg/g and 0.3103 μg/g (Table 4).

3.1.2. Precision Experiment. The results showed that the average contents of Al, As, B, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, P, Si, Ti, and Zn were 1.86, 0.22, 0.04, 31.09, 0.12, 0.04, 2.13, 11.34, 0.21, 5.11, 0.08, 3.06, 0.03, 3.46, 1.67, 0.05, and 1.07 mg/g, respectively. The RSD of the contents was between 0.27% and 3.87% ($n = 6$).

3.1.3. Stability Experiment. The results showed that the content of each element was stable within 24 h after samples preparation and was detected by the conditions listed in Table 3. The RSD values of various elements were between 0.35% and 4.70%.

3.1.4. Repeatability Experiment. The RSD values were 0.20%–3.54%, indicating that the method had good repeatability.

3.1.5. Sample Recovery. We acquired the average recoveries of Al, As, B, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, P, Si, Ti, and Zn were 119.83%, 121.55%, 121.77%, 104.38%, 114.67%, 120.33%, 110.31%, 104.83%, 113.16%, 117.04%, 115.57%, 111.88%, 121.83%, 113.79%, 115.74%, 108.68%, and

Table 4: Linear correlation and ranges and limits of trace elements reference substances.

Elements	Regression equation	Linear range (μg/mL)	Correlation coefficient	Limit of detection (μg/g)	Limit of quantitation (μg/g)
Al	$Y = 16455x + 2.4405$	0.1–60.0	1.0000	0.0005	0.0015
As	$Y = 44.772x - 1.0121$	0.1–10.0	1.0000	0.0480	0.1440
B	$Y = 1817x + 0.0907$	0.1–10.0	1.0000	0.0013	0.0039
Ca	$Y = 15662x + 56.219$	0.1–100.0	1.0000	0.0001	0.0003
Cr	$Y = 11792x - 0.0231$	0.1–10.0	1.0000	0.0002	0.0006
Cu	$Y = 16059x + 0.2513$	0.1–10.0	1.0000	0.0041	0.0124
Fe	$Y = 11077x - 3698.5$	0.1–60.0	0.9999	0.0005	0.0015
K	$Y = 194954x - 3.6305$	0.1–30.0	1.0000	0.0001	0.0003
Li	$Y = 1176.8x - 2.823$	0.1–10.0	1.0000	0.0042	0.0127
Mg	$Y = 198929x + 12.418$	0.1–10.0	1.0000	0.0001	0.0003
Mn	$Y = 54078x + 1.0599$	0.1–10.0	1.0000	0.0001	0.0003
Na	$Y = 573630x + 9.3303$	0.1–30.0	1.0000	0.0001	0.0003
Ni	$Y = 4611.7x + 0.103$	0.1–10.0	1.0000	0.0003	0.0009
P	$Y = 212.82x - 0.0129$	0.1–10.0	1.0000	0.1024	0.3103
Si	$Y = 2886.8x + 1601.6$	0.1–30.0	0.9996	0.0429	0.1300
Ti	$Y = 32280x - 2.9675$	0.1–10.0	1.0000	0.0018	0.0054
Zn	$Y = 8430.1x + 0.4132$	0.1–10.0	1.0000	0.0056	0.0170

109.64%, respectively. The RSD values were in the range of 1.84%–3.89%.

3.2. Content of Different Elements in Medicinal Materials

3.2.1. Samples from Different Areas and Tissues. In order to study the specific content of different elements in the collection areas and tissues, a three-dimensional characterization map was drawn for the detection of element content. It showed that the higher contents of different elements in roots, stems, leaves, and flowers in different collection areas were Al, Ca, Fe, K, Mg, Na, and P. The contents of elements in different tissues were as follows: flowers > leaves > stems > roots. The contents of elements in flowers of Maixiu Forest Farm from Henan County of Huangnan Prefecture were highest than those in other areas. However, the contents of different elements As, B, Cr, Cu, Li, Mn, Ni, Si, Ti, and Zn were lower in the plants (Table 5 and Figure 2).

3.2.2. Accumulation Contents from Different Areas and Tissues. The accumulation of various elements in different parts of each collection area was the highest in flowers: Zeku County > Guide County > Nangqian County > Henan County; the stems and leaves were the second, and the roots were the lowest. The results showed that the accumulation of various elements in the flowers: Maixiu Forest Farm from Henan County of Huangnan Prefecture (185.54 μg/g), was the highest, Guide County (136.32 μg/g) and Qilian County (53.80 μg/g) were the second, and Ji Gang Mountain (43.87 μg/g) from Henan County of Huangnan Prefecture was the lowest. The accumulation of various elements in the leaves: Nangqian County (44.40 μg/g), was the highest. The accumulation of various elements in the stems: Henan County of Huangnan Prefecture (92.25 μg/g), was the highest. The accumulation of various elements in the roots: Henan County of Huangnan Prefecture (20.81 μg/g and 19.17 μg/g), was the highest (Table 5 and Figure 3).

According to the analysis of the whole element accumulation contents, the accumulation content of elements in different tissues of collection areas was higher as follows: Nangqian County of Yushu Prefecture, Henan County of Huangnan Prefecture, Qilian County of Haibei Prefecture, and Guide County of Hainan Prefecture, while those of flowers > stems > leaves > roots. The amount of flower (43.87 μg/g – 185.54 μg/g) was the highest; the root (6.19 μg/g – 11.90 μg/g) was the lowest, and the leaf (33.56 μg/g – 44.40 μg/g) and the stem (27.96 μg/g – 92.25 μg/g) were higher in the Guide County from Hainan Autonomous Prefecture of *Corydalis conspersa* (Table 5 and Figure 3).

3.3. Analysis of Principal Components [14, 15]

3.3.1. Eigenvalues and Contribution Rate of Principal Components. In the results of principal component analysis, the KMO value is $0.647 > 0.6$, which indicates that factor analysis is suitable and significance value in the sphericity test is $0.000 < 0.05$ (significant level), indicating that there is correlation among variables and factor analysis. We can know the description of the original variables by the initial solution in the process of principal component analysis. The cumulative contribution rate of the total variance from three principal components is 82.46%, which means that the mathematical model established by the extracted three factors can clarify 82.46% of the experimental data. The contribution rate of principal component 1 is about 62%, which is more than half of the cumulative contribution rate of the whole principal component (Table 6).

3.3.2. Factor Load Matrix of Principal Component Analysis. The loading coefficients of Al, Ti, and Fe in the first principal component are 0.915, 0.931, and 0.893, respectively, which are all positive and significant contributions in the principal

Table 5: Determination results of trace elements from drugs of *Corydalis conspersa* and *Corydalis linarioides* (μg/g, $n = 3$).

Area and no. of tissues	Contents of different elements (μg/g)																
	Al	As	B	Ca	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Ni	P	Si	Ti	Zn
BHHJ-LJS-R	0.1590	0.0198	0.0014	2.5834	0.0063	0.0018	0.2215	1.1836	0.0177	1.0354	0.0101	0.3379	0.0046	0.5428	0.0213	0.0039	0.0440
BHHJ-LJS-S	0.2939	0.0016	0.0192	43.0778	0.0154	0.0124	0.3669	5.5344	0.0218	3.5696	0.0921	6.6219	0.0125	1.5856	0.0610	0.0102	0.0843
BHHJ-LJS-L	0.1585	0.0156	0.0296	20.3513	0.0154	0.0064	0.4838	5.0312	0.0300	3.3829	0.0383	3.5576	0.0881	1.3869	0.0557	0.0072	0.0705
BHHJ-LJS-F	2.0168	0.0959	0.0795	73.3182	0.2063	0.0696	3.3174	13.6937	0.6407	8.1114	0.1149	29.8339	0.0685	3.8760	0.2304	0.0650	0.5812
BHHJ-NQ-R	0.0964	0.0067	0.0199	5.7755	0.0103	0.0045	0.2016	1.6411	0.0243	2.3480	0.0140	0.3290	0.0031	1.2315	0.1171	0.0035	0.0738
BHHJ-NQ-S	0.2688	0.0095	0.0208	16.0705	0.0164	0.0038	0.3281	10.2757	0.0229	3.3568	0.0235	0.3247	0.0044	1.7999	0.0471	0.0069	0.0604
BHHJ-NQ-L	0.3666	0.0058	0.0623	26.0627	0.0131	0.0088	0.3749	9.1370	0.0214	3.7996	0.0499	2.4336	0.0038	1.7651	0.2201	0.0112	0.0595
BHHJ-NQ-F	1.7907	0.1944	0.0312	25.1130	0.1101	0.0353	2.0451	10.6436	0.1226	4.8897	0.0849	3.1478	0.0254	3.1420	1.1369	0.0595	1.2251
BHHJ-MXLC-R	0.4414	0.0078	0.0116	6.1523	0.0363	0.0143	0.8742	2.8408	0.0054	1.8621	0.0242	0.3401	0.0234	2.2952	5.7601	0.0095	0.1145
BHHJ-MXLC-S	0.1849	0.0154	0.0222	18.6912	0.0153	0.0085	0.2915	5.2315	0.0180	1.8095	0.0368	0.3914	0.0126	1.1573	0.0131	0.0065	0.0578
BHHJ-MXLC-L	0.2862	0.0105	0.0238	21.0956	0.0166	0.0096	0.4038	5.3325	0.0129	2.1006	0.0396	0.3780	0.0278	1.1397	5.8271	0.0102	0.0758
BHHJ-MXLC-F	1.3522	0.1262	0.1055	100.0932	0.0847	1.6989	2.1642	15.9234	0.1780	9.8788	0.2238	24.3429	0.0188	5.0706	23.8875	0.0451	0.3493
BHHJ-JGS-R	0.2170	0.0131	0.0722	8.9143	0.1031	0.0080	1.4777	4.0740	0.0210	2.4097	0.0242	0.2203	0.0055	1.4892	0.0337	0.0051	0.0823
BHHJ-JGS-S	0.1629	0.0050	0.0744	17.8859	0.0302	0.0044	0.6162	11.5855	0.0045	2.3596	0.0269	0.3364	0.0027	1.7058	0.0593	0.0054	0.0419
BHHJ-JGS-L	0.3159	0.0083	0.0944	20.9843	0.0249	0.0071	0.7128	8.6552	0.0125	3.2774	0.0519	0.1690	0.0028	1.7666	0.0888	0.0086	0.0702
BHHJ-JGS-F	1.8868	0.0469	0.5912	16.1990	0.0514	0.0277	2.9516	9.8618	0.0941	5.0048	0.0868	2.8924	0.0162	2.5725	1.0306	0.0525	0.5076
BHHJ-QL-R	0.0413	0.0086	0.0063	2.7290	0.0030	0.0029	0.1302	0.9669	0.0129	0.9783	0.0086	0.1713	0.0023	0.9476	0.1534	0.0014	0.0949
BHHJ-QL-S	0.3434	0.0084	0.0166	17.8769	0.0080	0.0082	0.6561	9.5423	0.0207	2.3654	0.0322	0.2606	0.0064	1.5725	0.0173	0.0108	0.0742
BHHJ-QL-L	0.6540	0.0114	0.0549	19.6020	0.0061	0.0078	0.7949	7.3228	0.0177	2.9379	0.0500	0.3688	0.0092	1.6296	0.0322	0.0144	0.0496
TLHJ-JGS-R	0.1551	0.0054	0.0065	7.1742	0.0142	0.0051	0.2283	1.8152	0.0302	0.8933	0.0232	2.1849	0.0035	0.5531	1.5728	0.0047	0.0628
TLHJ-JGS-S	1.7778	0.1214	0.3667	36.1462	0.1196	0.6910	1.9315	9.9361	0.2759	2.9696	0.2934	25.5791	0.0281	1.3541	10.0315	0.0406	0.5851

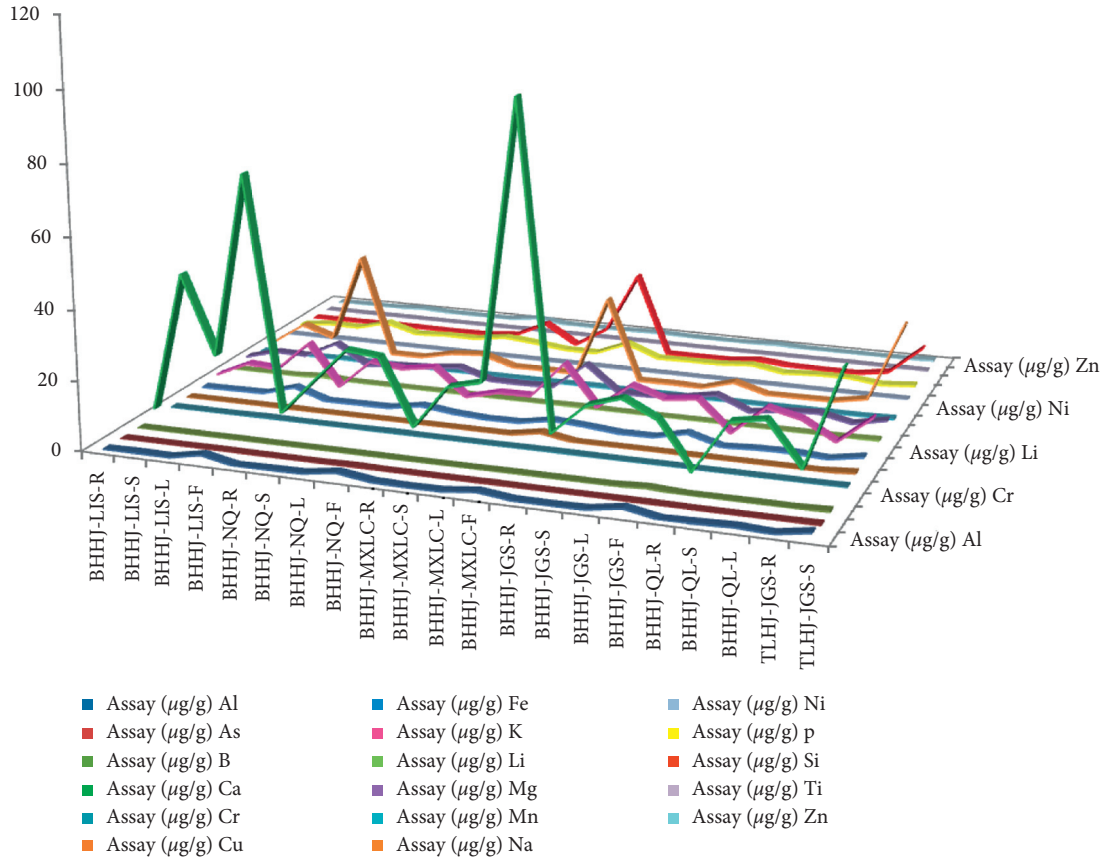

Figure 2: Contents of diverse elements from the different areas and tissues. Note: BHHJ-LJS-R/S/L/F: root, stem, leaf, and flower of Guide County from Hainan Autonomous Prefecture of *Corydalis conspersa*; BHHJ-NQ-R/S/L/F: root, stem, leaf, and flower of Nangqian County from Yushu Autonomous Prefecture of *Corydalis conspersa*; BHHJ-MXLC-R/S/L/F: root, stem, leaf, and flower of Zeku County from Huangnan Autonomous Prefecture of *Corydalis conspersa*; BHHJ-JGS-R/S/L/F: root, stem, leaf, and flower of Henan County from Huangnan Autonomous Prefecture of *Corydalis conspersa*; BHHJ-QL-R/S/L: root, stem, and leaf of Qilian County from Haibei Autonomous Prefecture of *Corydalis conspersa*; TLHJ-JGS-R/S: root and stem of Henan County from Huangnan Autonomous Prefecture of *Corydalis linarioides*.

component 1; the load coefficients of Cu, Si, and Zn in the second principal component are 0.698, 0.699, and −0.440, respectively, and the load coefficients of Zn are negative contribution rates, which play a major role in principal component 2; in principal component 3, the load coefficients of B, Li, and Ni are 0.649, −0.356, and −0.579, playing the main roles (Table 7).

3.3.3. Principal Component Vector. The elements Al, Fe, Mg, Na, P, and Ti play an important role in principal component 1; in principal component 2, elements Ca, Cu, Si, and Zn play an important role; in principal component 3, elements B, Li, and Ni play a main role (Table 8) [16].

3.3.4. Calculation of Principal Component Score. According to the calculation formula of principal components, the linear combination of the three principal components and the original 17 indicators can be obtained as follows:

$$Z_1 = 0.281X_1 + 0.260X_2 + 0.144X_3 + 0.256X_4 + 0.257X_5 + 0.204X_6 + 0.275X_7 + 0.239X_8 + 0.249X_9 + 0.271X_{10} + 0.252X_{11} + 0.269X_{12} + 0.138X_{13} + 0.261X_{14} + 0.184X_{15} + 0.286X_{16} + 0.229X_{17}.$$

$$Z_2 = -0.215X_1 - 0.093X_2 - 0.175X_3 + 0.285X_4 - 0.214X_5 + 0.480X_6 - 0.214X_7 + 0.093X_8 - 0.181X_9 + 0.135X_{10} + 0.173X_{11} + 0.099X_{12} - 0.179X_{13} + 0.127X_{14} + 0.480X_{15} - 0.205X_{16} - 0.302X_{17}.$$

$$Z_3 = 0.182X_1 + 0.126X_2 + 0.565X_3 - 0.236X_4 - 0.168X_5 + 0.137X_6 + 0.087X_7 + 0.012X_8 - 0.310X_9 - 0.157X_{10} + 0.210X_{11} - 0.176X_{12} - 0.504X_{13} - 0.104X_{14} + 0.152X_{15} + 0.087X_{16} + 0.178X_{17}.$$

Principal components 1 and 3 were mainly from flowers and stems of *Corydalis conspersa* collected from Hainan, Huangnan, and Yushu Autonomous Prefectures; principal component 2 was mainly from flowers collected from Huangnan, Hainan, and Yushu Autonomous Prefectures; and the top five principal components were also from Huangnan, Hainan, and Yushu Autonomous Prefectures (Table 9 and Figure 3).

3.4. Cluster Analysis. Taking square Euclidean distance as the measurement criterion, the ward least variance method was used to cluster. The 21 samples were divided into three categories: the roots of *Corydalis conspersa* and *Corydalis linarioides* from different collection areas belonged to the first group (nos. 1, 5, 9, 17, and 20), the stem and leaf of *Corydalis* belonged to the second category (nos. 2, 3, 6, 7, 14, 15, 18, and 19), and the flower

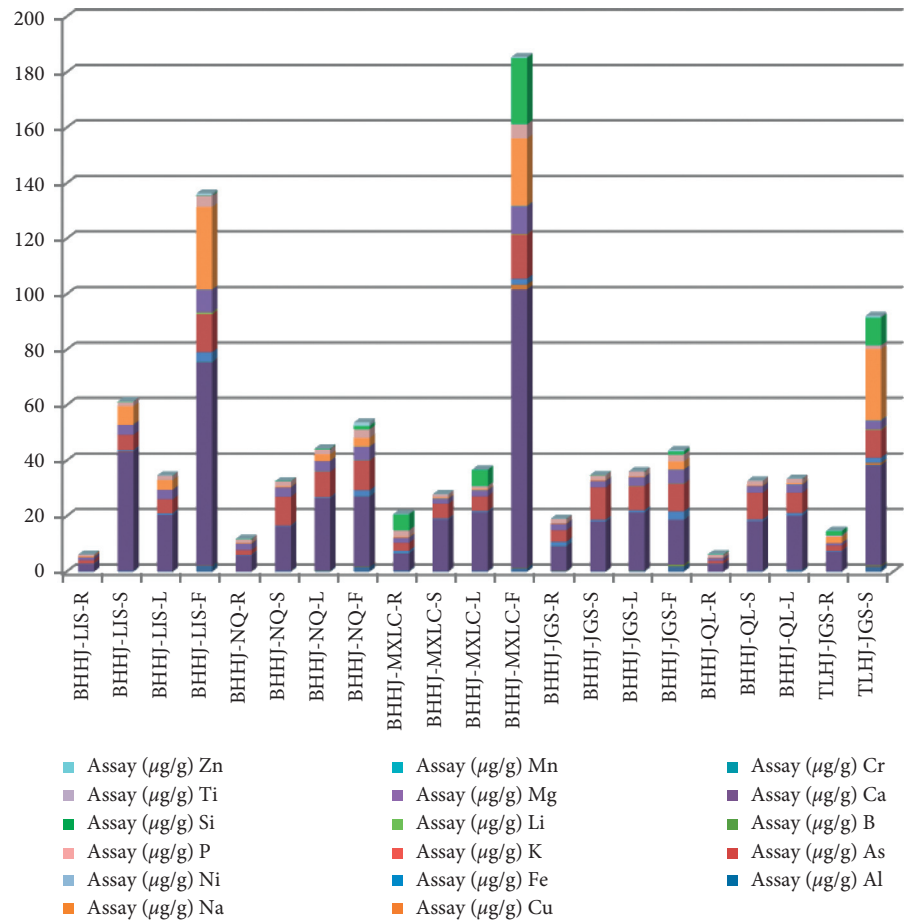

Figure 3: Accumulation content of elements from the different areas and tissues (note: the same as the Figure 2).

Table 6: Eigenvalue and variance contribution rate of principal component analysis.

Principle component	Eigenvalue	Contribution (%)	Accumulating contribution (%)
1	**10.580**	**62.236**	**62.236**
2	**2.117**	**12.454**	**74.691**
3	**1.321**	**7.772**	**82.463**
4	0.919	5.405	87.868
5	0.805	4.738	92.606
6	0.535	3.146	95.752
7	0.343	2.017	97.769
8	0.167	0.983	98.753
9	0.087	0.512	99.265
10	0.054	0.319	99.583
11	0.032	0.188	99.771
12	0.021	0.121	99.892
13	0.012	0.072	99.964
14	0.003	0.021	99.984
15	0.002	0.011	99.996
16	0.001	0.003	99.999
17	0.000	0.001	100.000

and stems of *Corydalis* belong to the third category (4, 8, 12, 16, and 21), while the stems (10) and roots (13) of *Corydalis conspersa* are also in the first and second categories, and the leaves (11) of *Corydalis conspersa* are in the first category (Table 5 and Figure 4) [17, 18].

Table 7: Factor load matrix of principal component analysis.

Elements	1	2	3	Common factor variance
Al	**0.915**	−0.313	0.209	0.979
As	0.846	−0.135	0.145	0.755
B	0.468	−0.254	**0.649**	0.705
Ca	0.832	0.415	−0.271	0.939
Cr	0.837	−0.311	−0.193	0.835
Cu	0.663	**0.698**	0.158	0.951
Fe	**0.893**	−0.311	0.100	0.905
K	0.776	0.135	0.014	0.620
Li	0.810	−0.263	**−0.356**	0.852
Mg	0.881	0.197	−0.180	0.847
Mn	0.820	0.252	0.241	0.794
Na	0.876	0.144	−0.202	0.829
Ni	0.449	−0.261	**−0.579**	0.606
P	0.849	0.185	−0.120	0.770
Si	0.598	**0.699**	0.175	0.877
Ti	**0.931**	−0.299	0.100	0.965
Zn	0.746	**−0.440**	0.205	0.792

3.5. Scatter Plot of Three Principal Components in Samples. Three principal components in the sample were selected and plotted by SPSS 20.0 software. The flower (No. 4, 8, 12, and 16) of *Corydalis conspersa* and stems (No. 21) of *Corydalis linarioides* from different collection areas are clustered and

Table 8: Principal component vector.

Elements	Principal component Z_1	Principal component Z_2	Principal component Z_3
Al	**0.281**	−0.215	0.182
As	0.260	−0.093	0.126
B	0.144	−0.175	**0.565**
Ca	0.256	**0.285**	−0.236
Cr	0.257	−0.214	−0.168
Cu	0.204	**0.480**	0.137
Fe	**0.275**	−0.214	0.087
K	0.239	0.093	0.012
Li	0.249	−0.181	**−0.310**
Mg	**0.271**	0.135	−0.157
Mn	0.252	0.173	0.210
Na	**0.269**	0.099	−0.176
Ni	0.138	−0.179	**−0.504**
P	**0.261**	0.127	−0.104
Si	0.184	**0.480**	0.152
Ti	**0.286**	−0.205	0.087
Zn	0.229	**−0.302**	0.178

Table 9: Principal component score.

Samples	Principal component 1 score	Principal component 2 score	Principal component 3 score	Comprehensive score	Ranking
BHHJ-LJS-R	−2.884	−0.136	0.132	−1.802	20
BHHJ-LJS-S	−0.912	0.732	−0.505	−0.516	6
BHHJ-LJS-L	−1.052	−0.355	−2.050	−0.859	14
BHHJ-LJS-F	**7.364**	**−2.297**	**−3.141**	**4.053**	**2**
BHHJ-NQ-R	−2.517	0.080	0.005	−1.556	18
BHHJ-NQ-S	−1.433	0.394	−0.146	−0.854	13
BHHJ-NQ-L	−1.064	0.512	0.000	−0.599	7
BHHJ-NQ-F	**3.999**	**−2.530**	**0.681**	**2.227**	**4**
BHHJ-MXLC-R	−1.349	0.128	−0.207	−0.840	11
BHHJ-MXLC-S	−1.968	0.155	−0.158	−1.218	17
BHHJ-MXLC-L	−1.493	0.483	−0.312	−0.893	16
BHHJ-MXLC-F	**7.556**	**4.862**	**0.166**	**5.321**	**1**
BHHJ-JGS-R	−1.247	−0.595	0.024	−0.848	12
BHHJ-JGS-S	−1.409	0.307	0.148	−0.827	10
BHHJ-JGS-L	−1.144	0.257	0.283	−0.658	8
BHHJ-JGS-F	**2.828**	**−2.251**	**2.827**	**1.699**	**5**
BHHJ-QL-R	−2.969	−0.006	0.144	−1.837	21
BHHJ-QL-S	−1.452	0.213	−0.005	−0.878	15
BHHJ-QL-L	−1.151	0.068	0.183	−0.694	9
TLHJ-JGS-R	−2.647	0.067	0.117	−1.630	19
TLHJ-JGS-S	**4.945**	−0.088	**1.814**	**3.208**	**3**

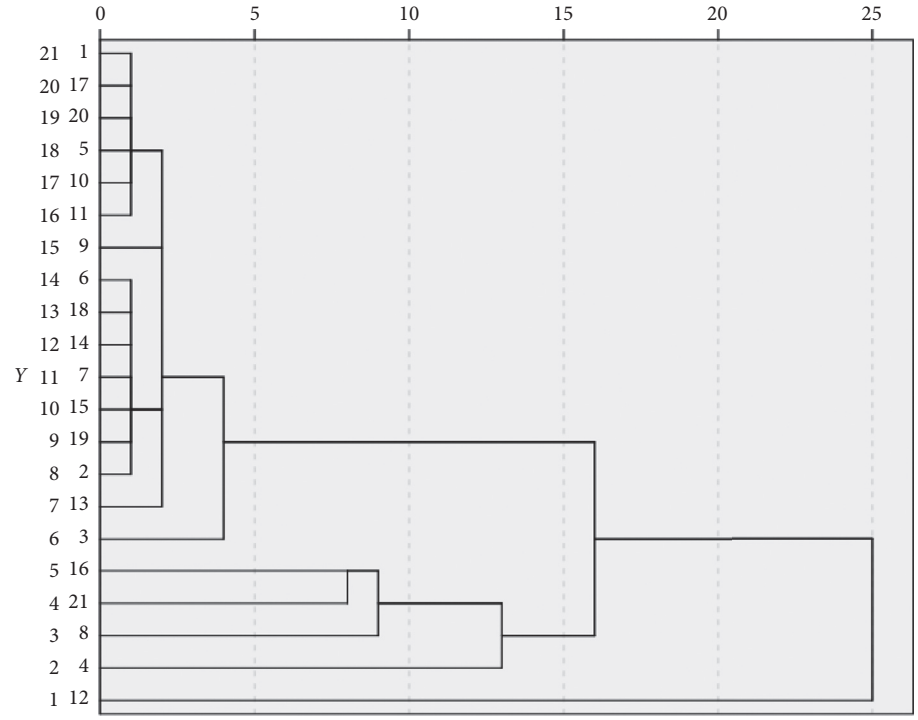

Figure 4: Cluster analysis.

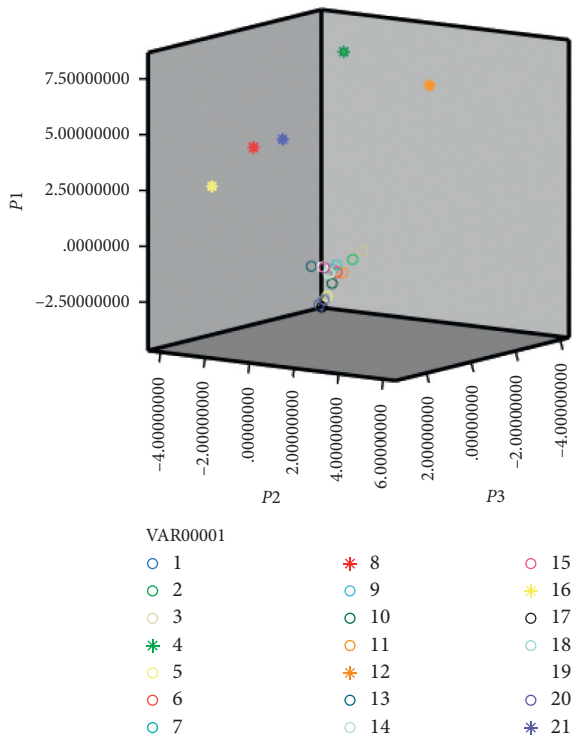

Figure 5: Scatter plot of principal components.

distributed in the same category containing high contents of type 1 and 3 characteristic components; and the roots, stems, and leaves of *Corydalis conspersa* and *Corydalis linarioides* from other collection areas are clustered and distributed in the same category with low contents of 1 and 2 characteristic components (Figure 5).

4. Conclusions

An suitable, precise, and selective ICP-AES method for the simultaneous determination of trace elements has been developed and validated from the TCM of *Corydalis conspersa and Corydalis linarioides*. According to the green industry standard for foreign trade and economic cooperation of medicinal plants and preparations issued by China in 2005 [19], the total amount of heavy metals should be less than or equal to 20.0 mg•kg^{-1} and the content of Pb ≤ 5.0 mg•kg^{-1}, Cd ≤ 0.3 mg•kg^{-1}, Cu ≤ 20.0 mg•kg^{-1}, As ≤ 2.0 mg•kg^{-1}, and Hg ≤ 0.2 mg•kg^{-1}. The content ranges of copper, arsenic, and chromium were 0.0018–1.6989 mg • kg^{-1}, 0.0016–0.1944 mg • kg^{-1}, and 0.0030–0.2063 mg • kg^{-1}, respectively. They all comply with the limit range of heavy metal. It showed that the growth and ecological environment of the medicinal materials were good and no pollution. The contents of elements have the great significance within the aspects of the plant physiology, the structure and efficacy of medicinal materials, and the ecological environment [20]. This research can provide a determination basis of trace elements in *Corydalis conspersa* and *Corydalis linarioides* so as to reveal the relationship between the functions of trace elements and plant growth through the further researches.

Data Availability

All data generated or analyzed during this study are included in this article. The original data related to the method validation are included as Supplementary Data (S1–S5).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Du Qing and Chen Zhi have made substantial direct and intellectual contribution to the work and approved it for publication. Du Qing, Cai Yanguo, and Chen Zhi contributed equally regarding the research works. All authors have made substantial contribution to the work and approved it for publication.

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Supplementary Materials

S1–S5 are the results of method validation. S1: results for the limits of detection and quantitation. S2: results for precision experiment. S3: results for stability experiment. S4: results for repeatability experiment. S5: results for the average recovery. (*Supplementary Materials*)

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