Comparative Study on Mineral Elements in the Roots of *Rheum tanguticum* from Qinghai-Plateau

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Abstract In the present paper, the authors analysed 10 mineral elements in the roots of *Rheum tanguticum* collected from 30 different habitats. The mean concentration values of the 10 elements decreased as follows: Ca >Mg>K>Fe>Mn>Cr>Zn>Ni>Cu>Se. Ca, Mg, K and Fe were abundant in this herb. Most elements varied over a wide range depending on the different habitats. The mineral element data were evaluated by principal component analysis to reveal the distribution pattern of elements in root. Four principal components (K-Ca factor, Cu factor, Mg factor and Zn-Se factor) of plant elements were selected. The authors' study provided a new scientific foundation for further studies and general application of this Chinese herb.

Keywords *Rheum tanguticum* Maxim. ex Balf; Mineral elements; Principal component analysis (PCA); Different habitats

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Introduction

Rheum tanguticum Maxim. ex Balf (Polygonaceae) is a famous perennial herbal medicine distributed in China, especially in Qinghai-Tibet Plateau, which grows in alpine meadows, forest edges, furrow valleys under forests, shrubs, and the edges of the road, at altitudes from 2 300 to 4 700 m[1]. The fleshy root and rhizome are usually used as medicine, with the effect of purgation, purging heat, loosening the bowels, curing gastric and renal disorders, removing bacterial dysentery, removing heat from the blood, clearing toxins away, promoting blood circulation, and removing blood stasis[2]. Most studies on rhubarb reported in the literature pertain to the chemical constituents and the efficacy, as well as the variety identification and quality evaluation and so on[3-6]. In the present paper, we analysed mineral elements in *Rh. tanguticum* under different wild environmental conditions from Qinghai-Plateau.

It is supposed that inorganic elements may be coordinated with organic compounds present in the herb, which can be used to treat for different diseases. People begin to pay more attentions to the inorganic elements, especially in herbs[7]. The 10 mineral elements in 30 plant samples were measured. The principal component analysis was applied to explain the pattern of mineral contents in *Rh. tanguticum* roots.

1 Experimental

1.1 Instrumentation, solutions and reagents

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For the analysis of nine elements (K, Ca, Mg, Fe, Cu, Mn, Zn, Ni and Cr), an atomic absorption spectrophotometry (TAS-986, PuXi Tongyong Company, Beijing, China) with air oxyacetylene flame was used. Se was determined with hydride-generation technique (WHG-102A, Haotianhui Company, Beijing, China). Working standard solutions were prepared from standards of single minerals. The concentrations of these working standard solutions (five standards for each element) were in the linear range of each element in the plant. The recovery percentages of each element were 98.26%~103.85%. Nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) were reagent analytical grade quality. All solutions and dilutions were prepared with double-distilled deionized water.

Table 1　Origins of materials

sample	Sites	Altitude /m	Latitude	Longitude
1	Guomaying, Guinan	2 770	35°53.61′	100°57.27′
2	Qunjia, Huangzhong	2 882	36°17.5′	101°40.71′
3	Maixiu2, Zeku	2 891	35°18.61′	101°56.32′
4	Maixiu1, Zeku	2 944	35°16.30′	101°55.98′
5	Yeniugou, Qilian	3 228	38°17.38′	99°49.57′
6	Tongde county	3 294	35°15.43′	100°39.49′
7	Duofutun, Zeku	3 309	35°14.96′	101°52.26′
8	Zhamashi, Qilian	3 412	38°21.05′	99°49.48′
9	Makehe2, Banma	3 415	32°46.45	100°47.07′
10	Duogongma, Banma	3 417	33°6.78′	100°34.13′
11	Lajia, Maqin	3 433	34°34.31′	100°33.48′
12	Jungong, Maqin	3 450	34°38.94′	100°36.49′
13	Banma county	3 517	32°55.44′	100°45.92′
14	Heri, Zeku	3 517	35°13.9′	101°0.13′
15	Qiake, Zeku	3 690	35°2.97′	101°29.09′
16	Jilong, Zeku	3 710	35°9.56′	101°12.2′
17	Zhiqin2, Banma	3 774	32°39.82′	100°30.94′
18	Zhiqin1, Banma	3 785	32°42.26′	100°26.60′
19	Duogongma, Banma	3 832	33°05.48′	100°29.08′
20	Jika3, Banma	3 891	32°51.07′	100°12.82′
21	Jika2, Banma	3 933	32°54.70′	100°10.12′
22	Daka, Banma	3 941	32°55.91′	100°09.37′
23	Shanggongma, Gande	4 032	33°52.13′	99°39.75′
24	Deang, Dari	4 041	32°17.39′	100°25.7′
25	Jianshe, Dari	4 055	33°40.42′	99°27.16′
26	Wosai, Dari	4 090	33°33.49′	99°56.61′
27	Dawu county	4 092	34°28.61′	100°23.06′
28	Makehe1, Banma	4 158	32°58.74′	100°20.34′
29	Manzhang, Dari	4 358	33°17.55′	100°22.91′
30	Jika1, Banma	4 484	32°55.57′	100°18.67′

1.2 Sample preparation

Rh. tanguticum roots were collected in August, 2007 from the Qinghai-plateau at altitude from 2 200 to 4 500 m in 30 different localities (Table 1). For each site, the individual plants were picked randomly, then taken and mixed together. The roots were slightly washed in field and again in the laboratory with bidistilled water in order to remove soil and avoid any surface contamination. These were then dried at 60 ℃ to constant weight and crushed to a homogeneous fine powder (100 mesh) in agate mortar. Accurately weighed samples of roots (4.000 g each) and 10 mL of HNO_3 were mixed, and then 2 mL of H_2O_2 were added after 1 h, and the samples were kept at 25 ℃ for 12 h before heating on a hot-plate at 70~100 ℃ for 3 h. Samples were allowed to cool and then transferred 100 mL volumetric flasks for the analysis.

2　Results and discussions

2.1 The elemental contents in *Rh. tanguticum* roots

The concentrations of 10 minerals in *Rh. tanguticum* roots were given in Table 2. The relative standard deviations were in the range from 0.2% to 2.5% confirming good reproducibility of the applied method. In 30 samples, the most elements showed a wide variability in different locations, which indicated that the different habitat characteristics (attitudes, latitudes, longitudes etc.) were important factors affecting the contents of mineral elements in this plant.

The mean values of 10 elements decreased as follows: Ca > Mg > K > Fe > Mn > Cr > Zn > Ni > Cu > Se. Cu, Ni and Se were found in trace ($<10\ \mu g \cdot g^{-1}$), while the concentrations of the other elements were much higher, especially Ca, K, Mg ($>1\ 900\ \mu g \cdot g^{-1}$) and Fe ($>100\ \mu g \cdot g^{-1}$). Zn was higher and Cu was lower, which maybe was correlative to this herb's antitumor function[8].

2.2 Element distribution patterns in *Rh. tanguticum* roots

To study mineral element patterns in the herb from different habitats, the principal component analysis was used to analyze the mass mineral element data in plant roots. It removes the highly inter-correlated nature of variations in mineral element concentrations. The eigenvalues and the percentages of variance (%) of principal components in plant elements were presented in Table 3. The first four principal components (PCs) represent 73.75% of all the variables information in plant root mineral contents. According to the Kaiser criterion[9], only the first four PCs were retained because subsequent eigenvalues were all less than one, which could basically represent and reflect the main information and the mutual relationship of the controlled characteristics among the mass indexes of plant root elements.

Another rotated component matrix of the first four principal components was given in Table 4. In the first principal component, Ca and K had large loading variable, which are multifunctional nutrients that formed an essential part of

Table 2 Mean concentrations and standard deviation (in $\mu g \cdot g^{-1}$) of elements in *Rh. tanguticum* roots

Samples	K	Ca	Mg	Fe	Cu	Mn	Zn	Ni	Cr	Se
1	2 025.4	1 963.8	2 086.2	76.8	2.2	21.3	33.0	5.5	42.4	1.37
2	1 899.0	2 101.8	1 526.0	131.4	2.9	27.8	33.0	5.7	42.7	1.16
3	2 012.4	1 932.3	2 077.0	225.4	4.1	30.9	30.8	6.3	42.9	1.44
4	1 999.5	801.3	1 390.3	100.1	3.1	19.8	30.9	4.6	42.4	1.31
5	1 759.3	2 455.9	2 084.7	57.0	2.5	148.2	30.7	8.1	42.8	1.00
6	1 906.4	2 077.0	2 254.5	137.1	4.9	31.2	30.7	4.1	42.6	1.13
7	1 746.7	2 548.8	1 740.2	66.9	2.0	116.2	31.8	10.5	43.4	1.61
8	1 832.7	2 507.9	1 833.3	111.4	4.8	136.4	30.7	13.3	43.5	1.25
9	1 852.8	2 400.1	1 778.2	109.6	4.0	67.1	30.9	6.2	42.4	1.22
10	2 019.7	2 243.9	1 998.7	90.9	2.3	87.4	31.0	4.8	42.4	0.83
11	1 935.8	2 355.7	1 783.6	111.6	5.1	32.5	31.2	8.2	42.7	1.31
12	1 936.5	2 047.6	2 216.2	196.5	3.1	31.6	31.3	3.6	42.8	1.20
13	1 854.9	2 266.6	2 125.3	131.6	3.2	40.5	30.9	5.2	42.1	1.27
14	1 882.0	2 116.4	1 993.5	64.8	2.2	19.1	31.4	3.6	42.4	1.31
15	1 664.8	2 426.0	1 759.4	56.9	2.4	99.0	31.3	7.5	42.9	1.19
16	1 926.9	1 805.7	1 892.4	85.7	3.3	19.6	30.7	5.5	42.4	1.31
17	1 926.2	2 148.6	1 879.4	70.0	3.0	115.1	31.3	4.7	41.9	1.21
18	1 886.1	2 163.4	1 897.3	81.4	1.8	47.4	31.1	3.9	42.0	1.15
19	2 153.3	699.5	1 560.2	103.1	4.1	33.8	32.6	6.2	41.5	1.19
20	2 035.2	1 903.9	1 928.7	115.5	2.4	23.9	30.9	4.1	41.8	0.56
21	1 866.7	2 276.0	2 172.4	109.6	1.6	131.7	31.7	7.2	41.7	1.39
22	1 867.1	1 790.6	1 770.8	132.2	3.0	24.9	30.8	4.1	41.7	0.62
23	1 874.9	2 239.2	1 845.1	88.6	2.2	45.6	31.0	4.6	42.4	1.19
24	1 901.5	2 364.4	1 894.3	240.3	2.3	60.6	31.2	8.5	42.6	1.06
25	1 831.8	2 341.0	1 783.6	103.4	2.5	47.8	31.6	5.9	42.6	1.12
26	1 854.1	2 165.5	2 323.4	145.5	2.9	55.2	30.8	5.2	42.3	1.24
27	1 876.4	2 147.9	1 850.6	72.3	2.5	22.6	30.7	4.1	42.4	1.19
28	1 963.5	2 204.0	2 116.5	91.5	2.7	51.1	31.3	6.0	41.7	1.23
29	1 951.1	2 170.8	2 152.1	179.9	2.8	89.4	31.4	4.6	42.3	1.09
30	1 782.0	2 404.1	1 938.3	128.1	2.0	58.0	30.7	5.9	41.8	1.58
Mean	1 900.8	2 102.3	1 921.7	113.8	2.9	57.8	31.2	5.9	42.4	1.19
SD	97.9	416.2	217.9	46.4	0.9	39.1	0.6	2.1	0.5	0.224

Table 3 Eigenvalues and percentage of variance(%) principal of plant root elements

Component	Initial eigenvalues		
	Total	Variance ratio/%	Cumulative ratio/%
1	3.05	30.53	30.53
2	1.70	16.96	47.49
3	1.58	15.81	63.30
4	1.05	10.45	73.75
5	0.81	8.08	81.82
6	0.67	6.70	88.52
7	0.50	5.02	93.54
8	0.32	3.16	96.70
9	0.20	1.98	98.68
10	0.13	1.32	100.00

many important enzymes[10]. In the second component, Cu had the largest loading variable. Cu is essential for a variety of biochemical processes and was needed for certain critical enzymes to function in the body. It is also involved in the functioning of the nervous system, in maintaining the balance of other useful metals in the body such as Zn and Mo, and is necessary for the normal function of the immune system[11]. It could be seen that Mg had the largest loading matrix in the third component. Mg is not only an important electrolyte but also is responsible for proper nerve and muscle function. It can works as a co-factor in more than 300 metabolic reactions[12]. The last component represented by Zn and Se could be deduced by analogy. Zn is the component of more than 270 enzymes and its deficiency in the organism is accompanied by multisystem dysfunction. Additionally, Zn and Se are responsible for stimulating growth of epidermal and epithelial cells, sperm manufacture, fetus development and proper function of immune response[13,14]. In this study, K and Ca, Cu, Mg, Zn and Se were the four main component elements, and can represent the majority of the mineral pattern in *Rh. tanguticum* roots, at the same time, represent the relationship between part efficacy of *Rh. tanguticum* roots and body physiological functions.

Biological effects of the estimated elements (K, Ca, Mg, Fe, Cu, Mn, Zn, Ni and Cr) in living systems strongly depend on their concentrations, and thus should be carefully controlled[15], especially when herbs and their products are used in human medicine as in the case with *Rh. tanguticum.* The elements of K, Ca, Mg and Fe were abundant in *Rh. tanguticum* roots. We hope that these results provide a reference for prescribing the dosage of *Rh. tanguticum* in medicine and some information for its planting. In this paper, the four principal components can only explain about 73.75% of the total variation, which implied that other factors influence the mineral elements of *Rh. tanguticum* roots, so further studies are needed.

Table 4　Loading matrix of the first four components in the rotated component matrix of plant root elements

Element	Principal component			
	1	2	3	4
K	−0.86	0.07	0.04	0.06
Ca	0.83	−0.06	0.34	−0.02
Mg	0.19	−0.22	0.86	−0.09
Fe	−0.29	0.39	0.69	0.01
Cu	−0.24	0.85	0.03	−0.14
Mn	0.77	0.02	−0.10	0.04
Zn	−0.28	−0.19	−0.26	0.76
Ni	0.60	0.56	−0.21	0.29
Cr	0.52	0.61	0.00	0.21
Se	0.22	0.15	0.10	0.75

Rotation Method: Varimax with Kaiser Normalization.

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