CHINESE GEOGRAPHICAL SCIENCE
Volume 11, Number 4, pp. 350 – 355, 2001
Science Press, Beijing, China

ANALYSIS OF BIOLOGICAL GEOCHEMISTRY OF CHEMICAL ELEMENTS IN *Betula ermanii* FOREST IN CHANGBAI MOUNTAINS, CHINA

LIU Jing-shuang, YU Jun-bao
(Changchun Institute of Geography, the Chinese Academy of Sciences, Changchun 130021, P. R. China)

ABSTRACT: Based on catalogue of biology and geochemistry of chemical elements, content characteristics and variation law of the large nutrient elements, the needful trace elements, the uncertain needful elements, the non-needful elements and the toxic elements in *Betula ermanii* trees are analyzed. The result shows that the content of the large nutrient elements in *Betula ermanii* trees is higher than that of other kinds of element; the contents of all kinds of elements in foliage with vigorous metabolism are higher than those in other parts; the content variations of the large nutrient elements and the needful trace elements with similar chemical property, geochemical property and biological function in different parts of *Betula ermanii* trees show the similar laws; but the other three kinds of elements variations are without laws. It is indicated that the variation of the needful elements in the plant follows a certain law, they are in relative equilibrium under undisturbed condition.

KEY WORDS: *Betula ermanii* forest; chemical element; variation law

CLC number: P593 Document code: A Article ID: 1002-0063(2001)04-0350-06

The Changbai Mountains Nature Reserve is a state-grade nature reserve, also is a component part of reserve net of international biosphere. Its area is large, the natural environment and ecosystem is protected completely. The natural elements and ecological environment in the reserve obviously appear in mountain feature. From mountain foot to top, the mountain are divided into four zones (mountain mixed conifer-broadleaf forest zone, mountain dark conifer forest, *Betula ermanii* forest zone and alpine tundra zone). Up to now, it basically keeps primitive nature landscape feature because of little mankind disturbance. A lot of researchers from the world are attracted to study the structure, function, energy flow and material flow of the forest ecosystem (FU *et al.*, 1984; FU *et al.*, 1982; HUANG *et al.*, 1989; HUANG *et al.*, 1982; LIU, 1993; LIU, 1988; ZHU *et al.*, 1991). Most of their research works focus on the chemical structure and material cycling in alpine tundra zone and broadleaf-Korean pine forest zone, and relative little in *Betula ermanii* forest zone. In order to enrich the research contents of the structure and function of different forest zones in the Changbai Mountains, the element composition, content characteristics and distribution law in different organs of *Betula ertmani* trees were approached in the paper.

1 INTRODUCTION

Betula ermanii forest zone occurs between 1800 –

Received date: 2001-07-13
Foundation item: Under the auspices of the Natural Science Foundation of the Chinese Academy of Sciences.
Biography: LIU Jing-shuang(1956 –), male, a native of Jilin Province, professor, doctor tutor. His research interest includes environment science. E-mail: liujingshuang@ mail. ccig. ac. cn.

2000m a. s. l. of the Changbai Mountains in China, and is a transitional zone from dark pine forest zone to alpine tundra zone. *Betula ermanii* forest is composed of pure *Betula ermanii* trees. It presents sparse woods or dispersed growth trees. The forest phase is simple. In general, we can see *Betula ermanii-Rhododendron aurenom* forest, *Betula ermanii-Vaccinium vitisidaea* forest and *Betula ermanii-Calamagrotis longidorfii* forest. The growth difference of *Betula ermanii* trees in the zone is obvious, the *Betula ermanii* trees grow well with high and straight trunk and dense trees in a shelter from the wind. With terrain rising, the *Betala ermanii* trees distribution is sparse with short and bend trunk. In *Betula ermanii* forest zone, the climate is severe cold; average temperature in July is 10 – 12℃, accumulated temperature of > 10℃ is 500 – 1000℃. Average precipitation is 1000 – 1200mm; the frost-free period is 65 – 70 days. The soil in the zone is mountain sward sylvogenic soil with slight alkalinity. Mother material is stone, gravel and sandy soil coming from collapsing and weathering. From soil surface to a depth of 10cm, organic matter content is higher than that of soil with sandy loam and granule structure in a depth of 10 – 20cm. In a depth of 20 – 40cm, soil is sandy soil, with granule structure, loose soil texture and little of organic matter content. Below 40cm, it is mother material layer with non-structure and much more gravel (LIU *et al.*, 1998).

2 MATERIALS AND ANALYSIS METHODS

In late growth season of *Betula ermanii* tree, five *Betula ermanii* trees were selected at random, and new leaves, new branches, different stem-grade branches, trunk, root, bark and litter were collected, respectively. At the same time, the soil samples in two profiles under the forest were collected. Air-dried plant samples were reduced to ashes under 450℃ and digested by $HNO_3 - HClO_4$, then their silicium were eliminated by using HF acid and their volumes were fixed by using 0. 1N HCl. The chemical elements contents of samples were determined by using ICP. The determined results were all within the permitted error range of instrument. The treatment and analysis of the soil samples are similar to the plant samples.

3 DISCUSSION

3. 1 The Content Features of Chemical Elements in Different Organs of *Betula ermanii* Trees

At present, more than 60 elements in organism have been recovered. Based on the functions of elements in organism, biologists and biological geochemistrists divide the elements into five types. They are the large nutrient element, the needful trace element, the uncertain needful element, the non-needful element and the toxic element (LIN, 1991). The contents of various elements in the plant are extremely different because of their different physiological functions (Table 1). The content of the large nutrient element is obviously higher than that of others in different organs of *Betula ermanii* trees (COTE and CAMIRE, 1987). The contents of Fe, Mn and Zn in the needful trace element type are higher. The content of Al is highest in the toxic element type. The content of the non-needful element and the uncertain needful element are higher than that of Co, Ni, Cr and Mo in the needful trace element type. The results show that plants absorb needful nutrient elements for choice, but they can't completely exclude other elements. The composition of those elements in the plant body shows the geochemistry features in *Betula ermanii* forest zone. Another feature of different types of chemical elements in different organs of *Betula ermanii* trees is that contents of all kinds of elements in foliage with vigorous metabolism are higher than that of other parts, because the foliage is the end of material transportation in plant (LARCHER, 1975). The materials that are absorbed by plant root are continuously transported to foliage through xylem and accumulated here. Additionally, one year old branch and eight years old branch also have high accumulation capacity of elements. The phenomenon is relative to ability of metabolism and distance of material transportation to end in different organs of plant (TURNER *et al.*, 1976). It can be testified by element contents in root. Root is also vigorous metabolism organ, but it is the beginning organ that plants absorb material from soil.

The different materials in root are continuously transported to other organs by concentration gradient, diffusion and transpiration, therefore accumulative amount of materials in root is relative little (RYAN and BORMANN, 1982). Only individual element with weak transporting ability shows high content in the beginning organ of material transportation or the parts near the beginning organ. The phenomenon shows that organs and ages of plant should be distinguished when element contents in plant are expressed, otherwise they would be lost reference and compared value. The third feature of elements contents in *Betula ermanii* body is that the elements contents in different tissues (vein, leaf flesh) of the same organ are different.

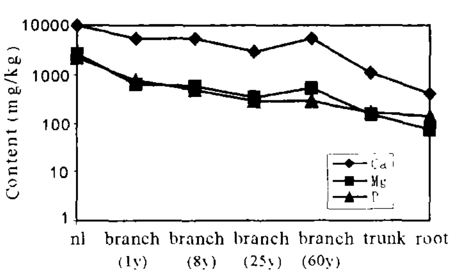
3.2 The Distribution Law of Different Types of Chemical Elements in *Betula ermanii* Tree

After materials are absorbed by plant root, they are transported to trunk, large-stem grade branch, small-stem grade branch and foliage in turn. Because transportation ability of different elements in the plant and physiological requirement of different organs of the plant to elements are different, the element contents in different organs are obviously different. But there is similar variation law of the large nutrient elements as well as the needful trace elements with the same chemical property and physiological function in the plant (FINCK, 1969). Fig. 1 shows that the content variation laws of Ca, Mg and P in the organs of the plant are very similar although their contents are extremely different, especially Ca and Mg. The main factor of this variation law is similar biological function of both elements, for example, the common adjusting hydration and mutual antagonistic action. In addition, the chemical properties of Ca and Mg and both transporting abilities in weathering crust and water have shown a lot of common characteristics. Fe, Co, Cu, Cr, Mn, Ni and Zn are all the needful trace elements for plant growth, but their contents variation in plant is not all identical because of different chemical properties and biological functions. The elements only with similar chemical properties and biological functions show identical variation. Co and Ni both are the fourth period of elements in iron group; both of their ion radius and electronegative property are similar; chemical and geochemical properties are basically identical. Both of their biological functions in

Table 1 The chimical element contents in different organs in *Betula ermanii* (mg/kg, dry weight)

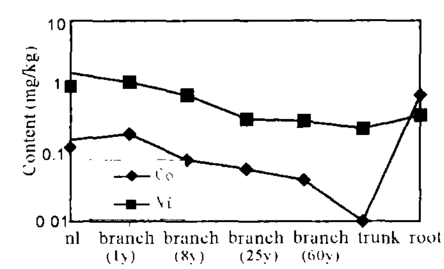
Types	Elements	New leaf	1-year-old branch	8-year-old branch	25-year-old branch	60-year-old branch	Trunk	Root	Bark	Litter
Large nutrient elements	Ca	9891.49	5218.58	5387.00	913.19	5550.83	1104.47	394.09	7641.87	7895.24
	Mg	2531.06	646.91	587.92	343.87	522.15	144.28	76.36	327.86	934.12
	P	2240.44	736.08	495.23	281.26	274.91	156.74	137.85	205.53	1548.35
Needful trace elements	Fe	210.87	167.85	209.62	48.61	42.49	122.37	217.08	786.25	704.03
	Co	0.17	0.20	0.08	0.06	0.04	0.01	0.77	0.46	0.94
	Cu	20.13	5.92	8.07	3.21	3.97	3.15	0.77	8.73	13.70
	Cr	0.45	0.41	0.25	0.02	0.12	0.06	0.41	1.03	1.23
	Mn	376.43	91.65	98.12	47.03	77.76	15.03	18.49	261.17	537.51
	Mo	0.28	0.24	0.47	0.07	0.05	0.19	1.37	1.56	1.37
	Ni	1.69	1.20	0.77	0.33	0.32	0.25	0.38	1.46	3.37
	Zn	270.90	241.06	180.25	100.35	151.52	37.96	22.50	188.35	269.95
Uncertain needful elements	Sr	24.94	21.08	18.00	11.60	19.69	4.21	2.87	27.07	24.57
	Ti	16.35	13.32	11.10	1.26	3.13	3.33	3.64	76.13	101.48
Toxic elements	Al	261.99	235.42	239.65	40.53	28.31	27.88	89.98	1460.40	933.10
	Cd	0.46	0.40	0.29	0.23	0.29	0.04	0.10	0.42	1.11
	Pb	3.24	1.68	0.88	0.001	0.11	0.36	2.16	3.07	5.68
Non-needful elements	Ba	76.00	78.95	61.23	45.76	73.05	13.20	13.01	80.54	53.90
	La	9.73	6.73	7.26	4.80	7.47	2.28	4.73	6.96	7.96

plants are the component of fixed-nitrogen enzyme. So both variation laws in Betula ermanii trees are very similar (Fig. 2). Fe in soil exists mainly in compound form in 2, 3 valences, Mo in soil exists in compound form in 4, 6 valences. The electronegative properties of Mo^{4+} and $Fe^{2(3)+}$ are approached, the ion radius of Fe^{3+} and Mo^{4+} is nearly equal, and both of their geochemical properties are also similar. Moreover, the existing forms of Fe and Mo in plant are metal organic compounds that are different with other trace elements. Both also are components of many kinds of enzymes and have nitrogen metabolism and oxidation-reduction. Though neither of them is component of chlorophyll, the foliage lose green while plant lacks Fe and Mo (FARGHALI, 1998). So the variation laws of Fe and Mo in *Betula ermanii* trees are similar because of their some common properties of ecological function (Fig. 3). Mn and Cu are components of many oxydases and have oxidation-reduction, photosynthesis and nitrogen metabolism. The plant absorbing forms are ions in 2 valence and chelates of Mn and Cu. Both of their contents in different organs of Betula ermanii trees shows certain regularity because of their common ecological functions (Fig. 4). Zn and Cr also are components of some enzymes and accelerate synthesis of chlorophyll. Zn partakes in transformation of carbohydrate and synthesis of growth hormone and can enhance cold resistance of plant. Cr can enhance activity of enzyme in plant, and strengthen disease resistance of plant. Though some biological functions of Zn and Cr are different, the variation laws of both contents in different organs of *Betula ermanii* are similar (Fig. 5). The above analysis results show that chemical property of element, biogeochemistry feature, biological function, and physiological requirement of plant for elements are the main factors of determining element content variation in plant. The results can be proved by the variations of Sr and Ti in the uncertain needful elements, La and Ba in the non-needful elements and Al, Cd and Pb in the toxic elements in plant, their variations in different organs of Betula ermaii trees are irregular. The reason is that they are not of any benefit to plant growing, mostly have toxicity. It is passive that plant absorbs them. So there is not biological law.



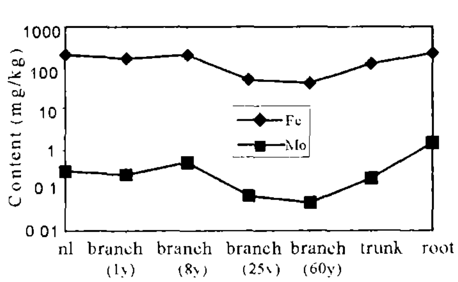
nl: new leaf; ly: 1-year-old; 8y: 8-year-old;
25y: 25-year-old; 60y: 60-year-old

Fig. 1 The variation law of the large nutrient elements in different organs of *Betula ermanii*



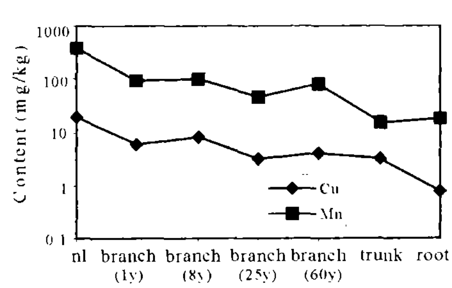
nl: new leaf; ly: 1-year-old; 8y: 8-year-old;
25y: 25-year-old; 60y: 60-year-old

Fig. 2 The variation law of Co and Ni in different organs of *Betula ermanii*



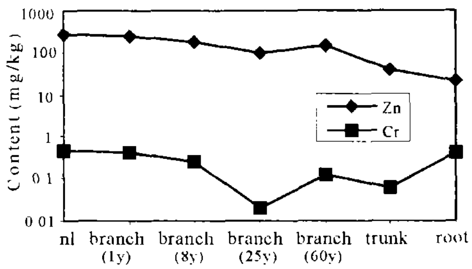
nl: new leaf; ly: 1-year-old; 8y: 8-year-old;
25y: 25-year-old; 60y: 60-year-old

Fig. 3 The variation law of Fe and Mo in different organs of *Betula ermanii*



nl: new leaf; ly: 1-year-old; 8y: 8-year-old;
25y: 25-year-old; 60y: 60-year-old

Fig. 4 The variation law of Mn and Cu in different organs of *Betula ermanii*



nl: new leaf; ly: 1-year-old; 8y: 8-year-old; 25y: 25-year-old; 60y: 60-year-old

Fig. 5 The variation law of Zn and Cr in different organs of *Betula ermanii*

3.3 The Relationship Between the Content of Trace Elements in Different Organs of *Betula ermanii* Trees and Soil

As everybody knows, most elements in plant come from soil, little of them from material exchange between foliage and air or rain. So there is a certain relationship between the elements in plant and in soil. The relationship is beneficial to assess the action and affecting extent of soil to plant. In order to explain the relation, the biological absorption coefficient was used to express the transference extent of elements from soil to plant. The calculation results show that the change range of biological absorption coefficient is great in different organs of plant in the same landscape (Table 2).

Table 2 has shown that the proportion of Fe, Co, Cr, Mo and Ni in the ash of root is higher than that in other organs, but the proportion of Cu, Mn, Zn, Ca and Mg in the ash of root is lower than that in other organs. The results show that the element accumulation extents in different organs of the plant are obviously different. According to the biological absorption coefficient in different organs of the plant, the remarkable characteristics of *Betula ermanii* trees is that Zn, Ca, Cu, Mg and Mn are accumulated, especially Zn. According to element accumulation extent in each organ of the plant, the accumulation extents of the same element in different organs of the same plant are different. This indicates that the strengths of biological function of the same element in different organs of the plant are different. Moreover, Table 2 has shown that the contents of elements with great biological absorption coefficients are not high in soil, for example, Cu, Zn, Mo and Ni. To the contrary, the biological absorption coefficients of elements with high contents in soil are low, for instance, Fe. The results indicate that the ability of accumulating elements of organisms goes by biology and geochemistry law under nature condition; it is dynamic balance under undisturbed condition. If artificial factors destroy the balance, the element component in plant will change greatly. For example, the content of Cu in soil is 13.11mg/kg. If its content is increased or decreased little, the biological absorption coefficient will change greatly. To the contrary, the content of Fe is increased or decreased 100mg/kg, the change of biological absorption coefficient is not obvious. This makes us know, in polluted environment, it is probable that the little content change of a certain element in soil can directly affect the normal growth of plant. In reverse, the contents of some elements change greatly, but the

Table 2 The biological absorption coefficients of different organs in *Betula ermanii*

Elements	Leaf	1-year-old branch	8-year-old branch	25-year-old branch	60-year-old branch	Trunk	Root
Fe	0.11	0.28	0.39	0.16	0.09	0.91	1.16
Co	0.11	0.41	0.19	0.26	0.10	0.001	5.11
Cu	24.26	23.24	35.13	24.57	20.54	54.52	9.54
Cr	0.23	0.69	0.46	0.06	0.26	0.46	2.17
Mn	8.59	6.73	8.00	6.73	7.53	4.86	4.28
Mo	1.59	4.40	9.51	2.51	1.21	15.28	29.17
Ni	1.22	2.79	1.98	1.51	0.97	2.61	2.77
Zn	30.00	85.95	71.31	69.69	71.27	59.62	25.2
Ca	30.97	52.61	60.26	57.20	73.83	49.04	12.51
Mg	7.92	6.52	6.58	6.75	6.94	6.41	2.42

plant growth is not affected. So, the biological absorption coefficient of a certain element should be fully considered when we assess soil effecte on plant..

4 CONCLUSIONS

(1) The contents of the large nutrient elements are obviously higher than that of other elements in different organs of *Betula ermanii*. In the needful trace elements type, the contents of Fe, Mn and Zn are higher than that of Cu, Co, Ni, Cr and Mo; in the toxic element type, the content of Al is higher than that of Pb and Cd; the contents of the uncertain needful elements and the non-needful elements are to range from the large elements to the trace elements.

(2) Contents of elements in foliage with vigorous metabolism are higher than that of other parts. The nearer distance of organs to transportation end is, the higher elements content in the organs is.

(3) The content variation laws of elements with similar chemical properties and geochemical characteristics and with similar biological functions in the plant are identical. The content variations of the large nutrient elements and the needful trace elements actively absorbed by plant are in agreement with the law. The variations of the toxic elements and the non-needful elements that are passively absorbed by plant are irregular.

(4) Under natural condition, the ability of accumulating elements of plants goes by biology and geochemistry law. It is in dynamic balance under undisturbed condition.

(5) The result of biological absorption coefficient analysis indicates that the ability of plant accumulating elements of plants from soil does not thoroughly determined by a certain element content in soil; the dominant factor is physiological requirement of plant for the element. So, in the course of researching the relation between plant and soil in polluted environment, the relation between the content variation of a certain element in polluted soil and biological absorption coefficient should be fully considered, and we shall assess accurately the influence extent of polluted soil to plant.

REFERENCES

COTE B, CAMIRE C, 1987. Tree growth and nutrient cycling in dense plantings of hybrid poplar and black alder[J]. *Can. J. For. Res.*,17: 516 – 523.

FARGHALI K A, 1998. Chlorophyll content and its stability in native species inhabiting the Egyptian desert[J]. *J. Arid Environ.*, 4(2): 163 – 175.

FINCK A, 1969. *Pflanzenernahrung in Stichworten* [M]. Kiel: F. Hirt.

FU De-yi *et al.*, 1984. Study of environmental chemistry background of forest ecosystem in Changbai Mountains [J]. *Forest Ecosystem Research*, 4: 178 – 196. (in Chinese)

FU De-yi *et al.*, 1982. Study of trace elements of dominant plants in Changbai Mountains [J]. *Scientia Geographica Sinica*, 2(3): 264 – 272. (in Chinese)

HUANG Xi-chou *et al.*, 1982. The chemical structure of ecological environment in Changbai Mountain Reserve[J]. *Acta Geographica Sinica*, 37(1): 26 – 31. (in Chinese)

HUANG Xi-chou, ZHAO Kui-yi, 1989. The contrast study of Lappland tundra, and Changbai Mountains tundra[J]. *Scientia Geographica Sinica*, 9(1): 8 – 15. (in Chinese)

LARCHER W, 1975. *Physiological Plant Ecology*[M]. New York: Spring-Verlag Berlin Heidelberg.

LIN Nian-feng, 1991. *Medicine Environment Geochemistry*[M]. Changchun: Jilin Science Technology Press. 77 – 80. (in Chinese)

LIU Jing-shuang, 1988. Study of materials cycling in *Vaccinium uliginosum* community in alpine tundra zone, Changbai Mountains [J]. *Resource, Environment* and *Regional Development Research*, (2): 1 – 7. (in Chinese)

LIU Jing-shuang, 1993. Study of materials cycling in *Rhododendron aureum* community in alpine tundra zone, Changbai Mountains[J]. *Acta Ecologica Sinica*, 13(1): 7 – 13. (in Chinese)

LIU Jing-shuang *et al.*, 1998. Analysis of biological geochemistry of chemical elements in *Betula ermanii* forest, Changbai Mountains, in China[J]. *Scientia Geographica Sinica*, 18 (5): 457 – 462. (in Chinese)

RYAN D F, BORMANN F H, 1982. Nutrient resorption in northern hardwood forests[J]. *BioScience*, 32: 29 – 32.

TURNER J, COLE D W, GESSEL S P, 1976. Mineral nutrient accumulation and cycling in a stand of red alder[J]. *J. Ecol.* 64: 965 – 974.

ZHU Yan-ming *et al.*, 1991. The geochemical analysis of trace elements in plants of alpine tundra zone in Changbai Mountains [J]. *Scientia Geographica Sinica*, 11(3): 244 – 252. (in Chinese)