# The influences of inorganic elements in soil on the development of famous - region *Atractylodes lancea* (Thunb.) DC

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## ABSTRACT

**Background:** *Atractylodes lancea* (Thunb.) DC., is an important medicinal plant in China. Recently, researches of *A. Lancea* were focused on chemical composition and genetics, only a few were concerned with soil factors. **Objective:** The aim was to discuss the relationship between geo-herbalism of *A. Lancea* (Thunb.) DC. and inorganic elements in soil. **Materials and Methods:** The contents of 15 kinds of inorganic elements in the rhizoma of *A. Lancea* (Thunb.) DC. and soils from various regions were determined with inductively coupled plasma-optical emission spectrometer and the data were analyzed with Statistical Package for the Social Sciences 20.0 software. **Results:** The contents of inorganic elements in rhizoma of *A. Lancea* and in soil with different geological background were different. The soils in the famous region contained high aluminum, iron, sodium and low sulfur content. The rhizoma of *A. Lancea* contained high aluminum, lithium, manganese and low iron, sulfur content. The famous-region crude drugs had a strong tendency to accumulate selenium, manganese. Ten characteristic elements of *A. Lancea* were K, Ca, S, Al, Li, Ti, Mn, Pb, Ni, SE. **Conclusion:** The contents of inorganic elements in rhizoma of *A. Lancea* showed a significant positive interrelationship with those in soil. It was identified that inorganic elements play an important role in forming authenticity *A. Lancea* (Thunb.) DC.

**Key words:** *Atractylodes lancea* (Thunb.) DC, geo-herbalism, inductively coupled plasma-optical emission spectrometer, inorganic elements, soil

## INTRODUCTION

The plant of *Atractylodes lancea* (Thunb.) DC., Asteraceae, named CangZhu in China belongs to the Asteraceae family. Its rhizome, commonly called *Rhizoma atractylodis* is used as an important crude drug against rheumatic diseases, digestive disorders, night blindness and influenza in China.[1] This medicine has been well-documented in Shen Nong Ben Cao Jing which is the first Chinese pharmacopoeia written in the Han dynasty about 200–100 BC.[2] The rhizomes of two species, *A. lancea* (Thunb.) DC. and *A. Chinensis* (DC.) Koidz., named MaoCangZhu and BeiCangZhu in China separately, have been used as *R. atractylodis* that embodied in the Pharmacopoeia of People's Republic of China 2010. The *R. atractylodis* produced with *A. lancea* from Maoshan region of Jiangsu province have been considered to be the "famous region drugs" with highest-quality and has been evidenced by long-term clinical practice.[3] Nowadays, due to the scarcity of famous-region herbs from Maoshan, *R. atractylodis* have been produced with *A. lancea* other areas. Thus, in order to determine clinical efficacy, the quality control of *R. atractylodis* materials from different geographical origins is extremely important.

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In recent years, many scholars have studied the geo-herbalism of *A. Lancea*,[4] but only focusing on research of chemical composition and genetics.[5-7] Zhao *et al*.[8] analyzed the relationship between essential oil variation and genetic variation of *A. lancea*. The findings showed that the environmental factors also play an important role in the forming of the geoherbs of *A. lancea* during the long-term adaptation, except for genetic factors. Guo *et al*.[9] studied the influence of inorganic elements in soil on the geolism of *A. lancea*.

In our research, the contents of inorganic elements in 16 plants and soils samples of *A. lancea* from five provinces have been analyzed by using inductively coupled plasma-optical emission spectrometer (ICP-OES) in order to find out the characteristic elements of *A. lancea*, discuss the relationship between geo-herb alism of *A. lancea* (Thunb.) DC. and inorganic elements and provide the basis for causes, planting and management of famous-region *A. Lancea*.

## MATERIALS AND METHODS

### Equipment, reagents, and working conditions

The devices used here included an ICP-OES (Varian, USA), dual array solid-state charge coupled device detector projection optical system, RYTON material atomizer, 40 MHz solid-state high-frequency self-excited generator, polyscience circulating water cooling system. ICP-OES operating parameters were as follows: Radio frequency power (1150 W), auxiliary gas flow rate (0.5 L/min), nebulizer gas flow rate (26 L/min), and carrier gas flow (1.2 mL/min). Reagents included HCl, $H_2O_2$ and $HNO_3$, which were analytical pure.

### Materials

*Atractylodes lancea* plants and soils were obtained from various geographical regions of China [Table 1]. All materials were identified to be the rhizomes of authentic *A. lancea* (Thunb.) DC., Asteraceae, by Professor Huangsheng Peng (School of Pharmacy, Anhui University of Chinese Medicine, Hefei, China). Samples were dried below 40°C and then crushed into a fine powder.

### Sample preparation

Plant samples (200 mg) were digested with a mixture of concentrated $HNO_3$ (10 mL) and $H_2O_2$ (2 mL) at 180°C. Soil samples (200 mg) were digested with a mixture of concentrated $HNO_3$ (15 mL), HCl (5 mL) and $H_2O_2$ (5 mL) at 150°C. After digestion, the solution was evaporated to dryness on an electric heating board at 170°C. After cooling (20 min), digests were diluted and transferred into a volumetric flask and made up to 50 mL with ultrapure water. Concentrations of inorganic elements in plants and soils samples were determined with ICP-OES.

### Statistical analysis

The correlation analysis, principal component analysis (PCA) and hierarchical clustering were performed with Statistical Package for the Social Sciences (SPSS) software (version 20.0, SPSS Inc., Chicago, USA). Our research selected the Ward's method.[10,11] In other words, during the clustering process, two subclasses that make the minimum increase of the total sum of squares of Euclidean distance among all samples of all subclass were combined into a single subclass. The Squared Euclidean Distance was selected as a measurement.

**Table 1: Origin of the medical materials**

| Population | Number of plant | Number of soil |
|---|---|---|
| Tongbai, Henan | A1 | S1 |
| Luanchuan, Henan | A2 | S2 |
| Lushi, Henan | A3 | S3 |
| Suizhou, Hubei | A4 | S4 |
| Baokang, Hubei | A5 | S5 |
| Songluo, Hubei | A6 | S6 |
| Songluo, Hubei | A7 | S7 |
| Zhenan, Shanxi | A8 | S8 |
| Xunyi, Shanxi | A9 | S9 |
| Huoshan, Anhui | A10 | S10 |
| Tongcheng, Anhui | A11 | S11 |
| Qianshan, Anhui | A12 | S12 |
| Maoshan, Jiangsu* | A13 | S13 |
| Mageng, Jiangsu* | A14 | S14 |
| Fangshan, Jiangsu* | A15 | S15 |
| Wawushan, Jiangsu* | A16 | S16 |

*Famous region

## RESULTS AND DISCUSSION

### Contents of inorganic elements in soils

There were differences among contents of inorganic elements in soils from different regions. Results showed that the soils in the famous region contained more Na, Cr, Fe, Ni, B and less S than unfamous regions. Comparing mean values, we found that contents of Al in famous-region soils were higher than unfamous-region that may be associated with the formation of traditional famous region. The contents of Al, Fe, Na may be used as the identification characteristics of the famous-region soil [Table 2].

### Contents of inorganic elements in plants

#### *Content analysis*

There were differences among contents of inorganic elements in plants from different regions. Results showed that famous-region herbs contained more Al, Li, P, Mn and less S, K, Fe than unfamous-region. Comparing mean values, we found that contents of Ti, Se, Pb in famous-region herbs were higher than unfamous-region. The famous-region *A. lancea* contained high Al, K, Ca [Table 3].

*Rhizoma atractylodis* belongs to the warm medicine. The substantial inorganic elements base of heat nature of Chinese herbs is decided by high Mn and low Fe.[12] Comparing Fe/Mn among famous-region and unfamous-region plants, we found that the Fe/Mn values of famous-region herbs were significantly lower than unfamous-region which manifested the inorganic elements characteristics of high Mn and low Fe.

#### *Principal component analysis*

We used SPSS (version 20.0, SPSS Inc., Chicago, USA) for the PCA, and three principal components were obtained. Among

**Table 2: Contents of inorganic elements in soils (mg/kg)**

| Sample | Aluminum | Lithium | Sulfur | Phosphorus | Sodium | Potassium | Calcium | Titanium | Chromium | Manganese | Iron | Nickel | Selenium | Lead | Boron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 13218.5 | 26.7475 | 261.225 | 164.8025 | 1854.725 | 5194.25 | 3743.75 | 393.95 | 16.48225 | 159.7875 | 8044.5 | 15.1545 | 1.1775 | 16.773 | 103.39 |
| S2 | 13469.75 | 39.3525 | 72.8125 | 125.0475 | 1377.95 | 4559 | 2859.75 | 351.775 | 24.627 | 232.9225 | 10534 | 25.855 | 0.1495 | 20.73975 | 65.09 |
| S3 | 11833 | 35.97 | 84.725 | 75.2225 | 1519.4 | 4925.5 | 1515.3 | 385.95 | 28.79 | 130.0625 | 7363.5 | 32.5975 | 2.34075 | 13.23075 | 52.55 |
| S4 | 11113 | 22.5765 | 152.4925 | 120.6925 | 1875.7 | 5473.75 | 2867 | 266.25 | 9.472 | 158.52 | 4943.25 | 14.579 | 0.628 | 17.3875 | 48.0025 |
| S5 | 8043.75 | 31.2275 | 136.3025 | 193.85 | 1668.825 | 3927.25 | 1804.075 | 55.3625 | 10.73725 | 229.6475 | 5065.5 | 18.18925 | 0.04575 | 15.01 | 84.1725 |
| S6 | 9661 | 32.5875 | 215.255 | 182.995 | 1729.625 | 4686.5 | 1877.65 | 18.05975 | 13.76725 | 247.7375 | 7317.75 | 21.2295 | 3.7815 | 13.75825 | 91.01 |
| S7 | 7697 | 30.1875 | 268.65 | 231.95 | 1707.65 | 4055.25 | 3275 | 198.005 | 20.2545 | 148.3575 | 6662.25 | 14.23725 | 0.1695 | 13.81375 | 56.125 |
| S8 | 10559.75 | 29.2075 | 426.6 | 327.65 | 1965.025 | 5194.25 | 7895.5 | 43.4275 | 15.07925 | 192.35 | 8547.25 | 26.16 | 3.436 | 22.73 | 100.2025 |
| S9 | 11909.5 | 40.59 | 193.5875 | 213.7825 | 1508.8 | 5792.25 | 4525.75 | 129.3175 | 19.1575 | 273.3 | 8995.5 | 24.6775 | 1.0725 | 15.1205 | 88.045 |
| S10 | 10252 | 7.52375 | 76.0925 | 88.715 | 1548.65 | 3482.75 | 1676.3 | 302.65 | 15.44375 | 259.95 | 7740 | 16.89875 | 2.1065 | 26.3725 | 88.885 |
| S11 | 6387 | 7.50175 | 82.0075 | 170.2125 | 1480.65 | 3584.5 | 2135.15 | 494.15 | 10.97925 | 131.12 | 5648 | 10.75525 | 1.85075 | 23.6075 | 52.815 |
| S12 | 10347 | 9.4055 | 122.97 | 82.7725 | 1347.5 | 1668.275 | 1268.7 | 128.2475 | 8.149 | 212.56 | 4788.75 | 8.87025 | 5.7275 | 23.6075 | 51.18 |
| S13 | 14411.25 | 25.8175 | 10.44925 | 116.675 | 2317.6 | 3539 | 2523.25 | 145.5775 | 34.16 | 345.275 | 12970 | 30.925 | 0.27075 | 21.64225 | 130.1525 |
| S14 | 13442.25 | 23.15825 | 14.253 | 181.885 | 2442.425 | 3532 | 1945.05 | 134.9425 | 35.8525 | 265.925 | 12117 | 31.4025 | 0.3425 | 17.20225 | 131.655 |
| S15 | 13305.25 | 26.595 | 18.72475 | 285.2 | 2793.5 | 4543.75 | 2940.25 | 258.95 | 30.2725 | 193.285 | 10579.75 | 32.85 | 0.366 | 30.3275 | 126.1425 |
| S16 | 16488 | 35.89 | 12.53125 | 142.835 | 2051.55 | 4162 | 2770.25 | 182.4275 | 36.7325 | 285.95 | 13098.25 | 32.095 | 0.307 | 18.48075 | 129.1675 |
| Mean | 11383.625 | 26.52114063 | 134.2923906 | 169.0179688 | 1824.348438 | 4270.017188 | 2851.420313 | 218.0651406 | 20.62228125 | 216.671875 | 8400.953125 | 22.27976563 | 1.48575 | 19.36273438 | 87.4115625 |
| Maximum | 16488 | 40.59 | 426.6 | 327.65 | 2793.5 | 5792.25 | 7895.5 | 494.15 | 36.7325 | 345.275 | 13098.25 | 32.85 | 5.7275 | 30.3275 | 131.655 |
| Minimum | 6387 | 7.50175 | 10.44925 | 75.2225 | 1347.5 | 1668.275 | 1268.7 | 18.05975 | 8.149 | 130.0625 | 4788.75 | 8.87025 | 0.04575 | 13.23075 | 48.0025 |
| SD | 2672.523709 | 10.52693865 | 115.5934837 | 71.18143916 | 408.2219868 | 1011.574934 | 1599.898309 | 139.3131203 | 9.815676633 | 61.91467072 | 2780.480659 | 8.327664205 | 1.639831511 | 5.010849757 | 30.79826464 |
| Variation | 7142382.975 | 110.8164374 | 13361.85347 | 5066.79728 | 166645.1905 | 1023283.848 | 2559674.598 | 19408.14547 | 96.34750776 | 3833.42645 | 7731072.693 | 69.34999111 | 2.689047383 | 25.10861529 | 948.5331049 |

SD: Standard deviation

**Table 3: Contents of inorganic elements in herbs (mg/kg)**

| Sample | Aluminum | Lithium | Sulfur | Phosphorus | Sodium | Potassium | Calcium | Titanium | Chromium | Manganese | Iron | Nickel | Selenium | Lead | Boron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 1755.925 | 3.13475 | 75.62 | 159.975 | 1390.375 | 6166.75 | 3443.5 | 28.3375 | 1.68725 | 37.1425 | 1557.35 | 5.5175 | 2.60875 | 3.78625 | 38.6975 |
| A2 | 1357.425 | 4.546 | 672.1 | 492.275 | 1733.775 | 11763.75 | 5307.25 | 4.902 | 15.2975 | 28.6325 | 1682.225 | 7.1445 | 2.96725 | 2.21125 | 120.1775 |
| A3 | 6.125 | 2.4775 | 735.75 | 6.8225 | 3156.25 | 9067.25 | 4241 | 0.09125 | 0.738 | 35.6225 | 1503.082 | 9.608 | 2.0475 | 0.50725 | 98.3825 |
| A4 | 536.225 | 2.056 | 424.575 | 154.44 | 1522.75 | 11550 | 5416 | 0.989 | 10.225 | 29.52 | 2099.125 | 5.282 | 0.0355 | 2.09875 | 79.6725 |
| A5 | 1448.125 | 4.3335 | 654.575 | 538.2 | 2196.425 | 7786.25 | 4109.75 | 19.18775 | 5.28525 | 8.3075 | 2103.4 | 16.22825 | 1.16875 | 5.1635 | 115.045 |
| A6 | 1859.65 | 5.521 | 565.75 | 298.5 | 2320.95 | 7341.25 | 4706.25 | 12.3815 | 7.342 | 13.7375 | 2282.875 | 14.81475 | 3.031 | 5.94525 | 111.67 |
| A7 | 987.925 | 2.866 | 417.5 | 411.7 | 1723.325 | 12747.75 | 3381.75 | 16.59125 | 2.437 | 16.16325 | 1183.8 | 5.41125 | 1.83225 | 4.151 | 31.2525 |
| A8 | 519.875 | 4.2125 | 162.2325 | 322.505 | 1345.75 | 7263.25 | 5582.25 | 9.375 | 4.6425 | 28.2375 | 1969.05 | 6.44425 | 7.17075 | 5.55 | 180.9312 |
| A9 | 515.375 | 2.50225 | 318.1 | 195.39 | 1656.05 | 7150.75 | 4477.25 | 8.407 | 8.29875 | 23.27175 | 834.25 | 5.137 | 1.882 | 3.025 | 116.5425 |
| A10 | 1434.45 | 2.138 | 968.9 | 301.75 | 2486.675 | 10524 | 6243 | 58.0225 | 6.8575 | 34.98 | 1831.25 | 19.614 | 1.14475 | 18.19375 | 83.8575 |
| A11 | 398.625 | 1.6295 | 764 | 455.85 | 2074.875 | 12383.25 | 3166 | 0.71675 | 5.90825 | 29.4075 | 1269.975 | 11.9915 | 1.6625 | 4.006 | 120.9925 |
| A12 | 370.2 | 1.60025 | 585.6 | 540.575 | 1507.75 | 8513.5 | 4921 | 10.81325 | 13.26375 | 32.555 | 1219.675 | 5.672 | 4.21775 | 6.2 | 124.135 |
| A13 | 3837.25 | 8.43625 | 22.2515 | 558.025 | 1714.175 | 4894.75 | 3405 | 36.73 | 6.177 | 112.5025 | 901.5 | 12.7065 | 5.6715 | 6.6115 | 120.9625 |
| A14 | 3054.25 | 7.26975 | 36.2075 | 548.475 | 2132.775 | 5131 | 3728.25 | 28.7525 | 5.09 | 93.3975 | 163.5 | 13.0545 | 4.46675 | 9.61775 | 100.67 |
| A15 | 2999 | 6.68425 | 46.85 | 566 | 1897.25 | 5170.75 | 3748.75 | 31.3375 | 5.55975 | 96.97 | 197 | 13.1445 | 7.24 | 8.1655 | 94.3825 |
| A16 | 3470.75 | 8.3 | 46.77 | 590.45 | 1958.975 | 5166.5 | 3629.25 | 37.065 | 5.51775 | 101.855 | 420.5 | 11.963 | 6.357 | 7.62075 | 98.9725 |
| Mean | 1534.448438 | 4.23171875 | 406.0488438 | 383.8082813 | 1926.132813 | 8288.796875 | 4344.140625 | 18.98123438 | 6.520453125 | 45.14390625 | 1326.159813 | 10.23334375 | 3.344 | 5.80334375 | 102.2714813 |
| Maximum | 3837.25 | 8.43625 | 968.9 | 590.45 | 3156.25 | 12747.75 | 6243 | 58.0225 | 15.2975 | 112.5025 | 2282.875 | 19.614 | 7.24 | 18.19375 | 180.9312 |
| Minimum | 6.125 | 1.60025 | 22.2515 | 6.8225 | 1345.75 | 4894.75 | 3166 | 0.09125 | 0.738 | 8.3075 | 163.5 | 5.137 | 0.0355 | 0.50725 | 31.2525 |
| SD | 1212.567886 | 2.355075945 | 312.2981424 | 182.1367325 | 467.6692753 | 2756.480075 | 931.4668896 | 16.40009322 | 3.857236536 | 34.54069456 | 678.2777609 | 4.579908069 | 2.259329362 | 4.088056505 | 34.8012659 |
| Variation | 1470320.877 | 5.546382707 | 97530.12975 | 33173.78932 | 218714.5511 | 7598182.402 | 867630.5664 | 268.9630577 | 14.87827369 | 1193.059581 | 460060.7209 | 20.97555792 | 5.104569167 | 16.71220599 | 1211.128108 |

SD: Standard deviation

them, the contribution rate of the first and second principal components was 47.87% and 22.48%, respectively, and a cumulative contribution rate of 94.53%. The first principal component were K, Li, S, Al, Mn, Se and the second principal component Ca, and the third principal component Ti, Pb, Ni [Table 4]. We can conclude that 10 kinds of characteristic elements of *A. lancea* were K, Ca, S, Al, Li, Ti, Mn, Pb, Ni, Se.

By using the percentage of variance of each principal component, we calculated the comprehensive scoring formula: F =0.47872 $F_1$ + 0.22486 $F_2$ + 0.24175 $F_{3.}$ The comprehensive factor score and sorting of *A. lancea* from different regions were shown in Table 5. The score of Maoshan Jiangsu, Huoshan Anhui, Wawushan Jiangsu, Mageng Jiangsu, Fangshan Jiangsu ranked 1–5, proving that the famous-region *A. lancea* conformed to the above characteristics of inorganic element. Four famous-region herbs contained high K, Al, Li, Ti, Mn, Se, Pb and low S, Ca. The *A. lancea* from Huoshan Anhui contained high K, S, Ti, Pb, Ca. However, the score of Tongcheng Anhui was lowest, and the *A. lancea* from Tongcheng contained low Li, Ti, Pb.

The first two principal components were used to build the scatter diagram [Figure 1]. The samples were divided into two groups: Group 1 contained four samples as famous-region *A. lancea*; group 2 included 12 samples of unfamous-region *A. lancea*.

### *Correlation analysis*

The correlation analysis among 15 kinds of inorganic elements was conducted [Table 6]. Results showed that Al with Mn, S with K and Ni with Pb etc., ($P < 0.01$) were significantly correlated. Mn with *P* etc., ($P < 0.05$) were correlated. It might indicate that the absorption of these

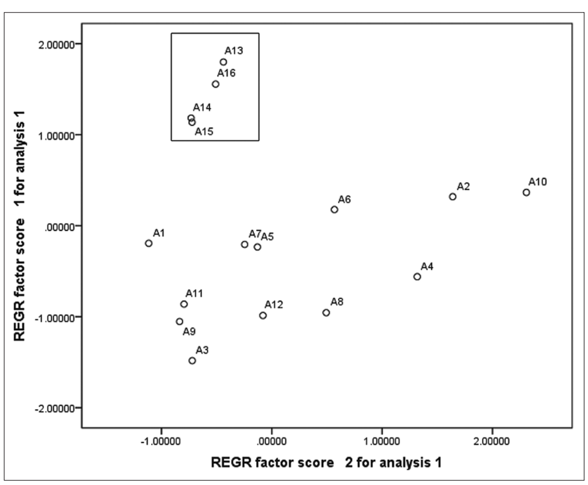


**Figure 1:** Principal component analysis results of the 16 *Atractylodes lancea* samples. We used Statistical Package for the Social Sciences for the normalization data processing, and the extraction standard was the characteristic value of >1. The first two principal components were used to build the scatter diagram

**Table 4: Component loading matrix**

| Aluminum | Lithium | Titanium | Manganese | Phosphorus | Nickel | Lead | Selenium | Boron | Potassium | Sulfur | Calcium | Iron | Chromium | Sodium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.760 | 0.785 | 0.485 | 0.728 | 0.333 | 0.240 | 0.231 | 0.705 | 0.158 | −0.99 | −0.770 | −0.36 | −0.57 | −0.26 | −0.08 |
| −0.455 | −0.34 | −0.14 | −0.38 | −0.47 | 0.095 | 0.075 | −0.03 | 0.462 | −0.11 | 0.225 | 0.784 | 0.210 | 0.240 | 0.003 |
| 0.468 | 0.367 | 0.547 | 0.223 | 0.295 | 0.516 | 0.580 | 0.020 | −0.03 | 0.039 | 0.134 | 0.468 | 0.259 | 0.411 | 0.071 |

elements was accumulated (namely certain homogeneity). On the contrary, K with Al and S with Se ($P < 0.01$), etc., were significantly negatively correlated. Fe with Se ($P < 0.05$) was negatively correlated.

### *Cluster analysis*

The results were processed by SPSS cluster analysis [Figure 2]. The 16 samples could be gathered into two groups: Famous-region *A. lancea* were clustered into a group; unfamous-region *A. lancea* were clustered into a group. The cluster analysis outcomes were consistent with those of the PCA.

## Correlation analysis between plants and soils

### *Correlation coefficient*

The inorganic elements of *A. Lancea* from Luanchuan Henan,

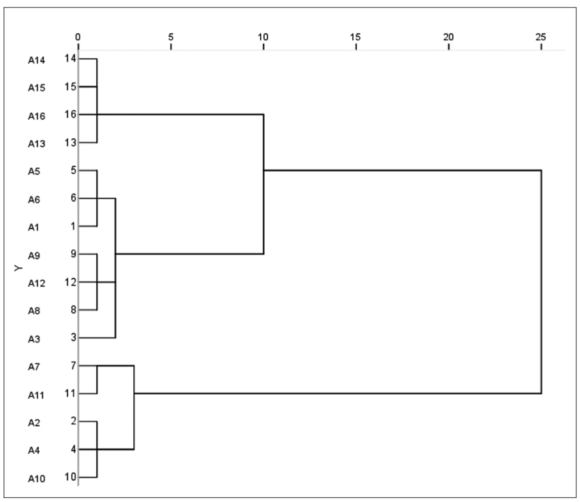


**Figure 2:** Cluster analysis results of the 16 *Atractylodes lancea* samples using Statistical Package for the Social Sciences software. Ward's method was applied and the squared Euclidean distance was chosen as the measurement

**Table 5: The comprehensive factor score and sorting**

| Population | F1 | F2 | F3 | F | Rank |
|---|---|---|---|---|---|
| Tongbai, Henan | −0.19 | −1.11 | 0.46 | −0.23 | 11 |
| Luanchuan, Henan | 0.31 | 1.63 | −0.88 | 0.30 | 7 |
| Lushi, Henan | −1.48 | −0.72 | 0.178 | −0.82 | 15 |
| Suizhou, Hubei | −0.56 | 1.31 | −0.34 | −0.05 | 9 |
| Baokang, Hubei | −0.23 | −0.13 | 0.31 | −0.06 | 10 |
| Songluo, Hubei | 0.17 | 0.56 | 0.73 | 0.39 | 6 |
| Songluo, Hubei | −0.20 | −0.24 | −2.31 | −0.71 | 14 |
| Zhenan, Shanxi | −0.95 | 0.49 | 1.59 | 0.04 | 8 |
| Xunyi, Shanxi | −1.05 | −0.83 | 0.79 | −0.50 | 13 |
| Huoshan, Anhui | 0.36 | 2.30 | 0.17 | 0.73 | 2 |
| Tongcheng, Anhui | −0.86 | −0.79 | −2.04 | −1.08 | 16 |
| Qianshan, Anhui | −0.98 | −0.08 | 0.56 | −0.35 | 12 |
| Maoshan, Jiangsu | 1.79 | −0.43 | 0.11 | 0.79 | 1 |
| Mageng, Jiangsu | 1.18 | −0.73 | 0.25 | 0.46 | 4 |
| Fangshan, Jiangsu | 1.13 | −0.72 | 0.27 | 0.45 | 5 |
| Wawushan, Jiangsu | 1.55 | −0.51 | 0.11 | 0.65 | 3 |

**Table 6: Correlation analysis among the inorganic elements of plants**

| | Aluminum | Lithium | Sulfur | Phosphorus | Sodium | Potassium | Calcium | Titanium | Chromium | Manganese | Iron | Nickel | Selenium | Lead | Boron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 1 | | | | | | | | | | | | | | |
| Lithium | 0.922** | 1 | | | | | | | | | | | | | |
| Sulfur | −0.637** | −0.676** | 1 | | | | | | | | | | | | |
| Phosphorus | 0.603* | 0.579* | −0.268 | 1 | | | | | | | | | | | |
| Sodium | −0.044 | −0.007 | 0.509* | −0.223 | 1 | | | | | | | | | | |
| Potassium | −0.686** | −0.725** | 0.739** | −0.261 | 0.073 | 1 | | | | | | | | | |
| Calcium | −0.407 | −0.364 | 0.464 | −0.302 | −0.004 | 0.299 | 1 | | | | | | | | |
| Titanium | 0.691** | 0.460 | −0.241 | 0.349 | 0.080 | −0.443 | −0.021 | 1 | | | | | | | |
| Chromium | −0.118 | −0.114 | 0.261 | 0.292 | −0.341 | 0.260 | 0.511* | −0.215 | 1 | | | | | | |
| Manganese | 0.839** | 0.796** | −0.679** | 0.499* | −0.022 | −0.663** | −0.405 | 0.542* | −0.128 | 1 | | | | | |
| Iron | −0.559* | −0.509* | 0.595* | −0.480 | 0.055 | 0.489 | 0.567* | −0.327 | 0.139 | −0.779** | 1 | | | | |
| Nickel | 0.456 | 0.365 | 0.252 | 0.328 | 0.616* | −0.217 | 0.026 | 0.606* | −0.162 | 0.257 | −0.008 | 1 | | | |
| Selenium | 0.570* | 0.698** | −0.683** | 0.515* | −0.262 | −0.683** | −0.182 | 0.286 | −0.066 | 0.682** | −0.532* | 0.035 | 1 | | |
| Lead | 0.418 | 0.218 | 0.064 | 0.339 | 0.174 | −0.210 | 0.282 | 0.855** | −0.015 | 0.320 | −0.174 | 0.699** | 0.187 | 1 | |
| Boron | −0.102 | 0.154 | 0.032 | 0.228 | −0.057 | −0.203 | 0.339 | −0.262 | 0.347 | 0.025 | 0.111 | 0.094 | 0.429 | −0.023 | 1 |

*$P<0.05$ correlated; **$P<0.01$ significantly correlated

Lushi Henan, Huoshan Anhui, Tongcheng Anhui, Qianshan Anhui were not correlated with corresponding soil. On the contrary, the inorganic elements from 11 other regions were obviously related [Table 7]. The results of our study were not the same with Guo *et al.*[9] which may be related to the quantities of samples. Thus, we speculated that *A. lancea* absorbed inorganic elements from the soil in two ways: Selective absorption (active absorption) and passive absorption.

### *Enrichment coefficient*

Enrichment coefficient (EC) is the EC for plant/soil system. It was calculated to assess the accumulations of elements from soils to plants, and it is described as the following formula:[13]

$$EC = \frac{[M]_{plant}}{[M]_{soil}}$$

$[M]_{plant}$ is the concentration of an element in the tissue of the plant (root or leaf), mg/kg, in dry matter;

$[M]_{soil}$ is the total concentrations of an element in soils where this plant is grown, mg/kg, in dry matter.

Famous-region *A. lancea* had a strong tendency to accumulate Se (average value 18.6) and good tendency to S, P, K, and Ca. However, the EC of other elements was low (<1). The EC of Fe of famous-region herbs was 8.3 times lower than unfamous-region herbs. But the EC of Se, Mn was 3.4 times and 2.5 times higher, respectively. This was probably due to the selective absorption and enrichment of some trace elements with medicinal plants regulating the body metabolism.[14] Therefore, EC characteristics can be used as a chemical feature of identifying famous-region *A. lancea*.

## CONCLUSION

The contents of inorganic elements in rhizoma of *A. lancea* and in soil with different geological background were different. Content analysis, correlation analysis, and enrichment analysis proved that famous-region herbs had a good tendency to accumulate Mn and bad to Fe which played an important role in the formation of the traditional famous-region *R. atractylodis*. The inorganic elements are one of the important causes of formation of famous-region *R. atractylodis*. Inorganic elements in *R. atractylodis* are closely related to those in soil.

By the results of the correlation analysis among 15 kinds of inorganic elements that toxic element Pb with essential element Ni etc., were significantly correlated and the absorption of these elements was accumulated, we may speculate that the influence of inorganic elements on the formation of famous-region herbs was not just about how much the content of them, but also about the contribution to growth, formation and effective components. These aspects need further research.

The results of PCA and clustering analysis showed that the inorganic element may be used as a standard to identify famous-region plants. Therefore, in addition to the traditional chemical method, the characteristics of inorganic elements may also be the basis of geo-authentic and effective characteristics research of traditional Chinese medicine.

**Table 7: Correlation analysis between plants and soils**

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 0.572*** | | | | | | | | | | | | | | | |
| S2 | | 0.343 | | | | | | | | | | | | | | |
| S3 | | | 0.307 | | | | | | | | | | | | | |
| S4 | | | | 0.458* | | | | | | | | | | | | |
| S5 | | | | | 0.550** | | | | | | | | | | | |
| S6 | | | | | | 0.565** | | | | | | | | | | |
| S7 | | | | | | | 0.438* | | | | | | | | | |
| S8 | | | | | | | | 0.603** | | | | | | | | |
| S9 | | | | | | | | | 0.441* | | | | | | | |
| S10 | | | | | | | | | | 0.35 | | | | | | |
| S11 | | | | | | | | | | | 0.411 | | | | | |
| S12 | | | | | | | | | | | | 0.15 | | | | |
| S13 | | | | | | | | | | | | | 0.581** | | | |
| S14 | | | | | | | | | | | | | | 0.433* | | |
| S15 | | | | | | | | | | | | | | | 0.529* | |
| S16 | | | | | | | | | | | | | | | | 0.517* |

*$P$<0.05 correlated; **$P$<0.01 significantly correlated

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