Assessment of Heavy Metal Content and Potential Ecological Risk in Soil and Siraitia grosvenorii from the Hilly Mountainous Area of Longsheng County: A Case Study of Baozeng Village (Postprint)

Authors: Zhang Denan, Zhou Longwu, Duan Chunyan, Chen Xiaxia, He Wen, Teng Qiumei, Sun Yingjie, Zhongfeng Zhang, Xu Guangping

Date: 2019-11-15T00:00:00+00:00

Abstract

In Longsheng County, Guilin City, one of the three major production areas of Siraitia grosvenorii, the heavy metal content in orchard soils and fruit quality affect the healthy development of the Siraitia grosvenorii industry. To explore the safety of Siraitia grosvenorii orchards in typical impoverished villages in the hilly mountainous areas of Longsheng County, this study investigated the contents of seven heavy metals (arsenic, copper, zinc, lead, cadmium, chromium, and mercury) in the soil and fruits of Siraitia grosvenorii from a typical orchard in Baozeng Village, and analyzed their potential ecological risks using the Hakanson index method. The results showed that: The heavy metal contents in the soil of Siraitia grosvenorii orchards in the hilly mountainous areas of Longsheng (0-10 cm, 10-20 cm) all met the National Soil Screening Values for Agricultural Land (GB15618-2018), with arsenic, copper, zinc, lead, cadmium, chromium, and mercury contents in the 0-10 cm soil layer being 3.67, 18.00, 58.39, 17.01, 0.10, 28.57, and 0.08 mg · kg ^{1}, respectively, and those in the 10-20 cm soil layer being 1.93, 12.56, 21.47, 10.51, 0.04, 17.09, and 0.02 mg · kg ^{1}, respectively.
The ecological risk status of heavy metals in both the 0-10 cm and 10-20 cm soil layers was generally at a slight ecological risk level, with comprehensive ecological risk indices of 105.29 and 38.96, respectively; the potential ecological risk order of different heavy metals in the 0-10 cm soil layer was mercury > cadmium > lead > copper > arsenic > zinc > chromium, with ecological risk values of 50.16 and 42.05 for mercury and cadmium, respectively, whose contribution rates to total heavy metal risk accounted for 47.6% and 39.9% of all heavy metals, respectively, reaching the moderate ecological risk level. In the 10-20 cm soil layer, the ecological risk order of the seven heavy metals was

cadmium > mercury > copper > lead > arsenic > chromium > zinc. , The contents of arsenic, copper, zinc, lead, cadmium, chromium, and mercury in Siraitia grosvenorii fruits from the study area were 0.00024, 0.273, 1.10, 0.0016, 0.00013, 0.00013, and 0.00012 mg · kg ^{1}, respectively, with their ecological risk status all at a slight risk level; the ecological risk order of the seven heavy metals was mercury > copper > cadmium > zinc > lead > arsenic > chromium, with a comprehensive ecological risk index of 0.21193, indicating negligible ecological risk. Therefore, the Siraitia grosvenorii promoted and cultivated in Baozeng Village, a typical impoverished village in the hilly mountainous areas of Longsheng County, meets the safety and quality standards.

Full Text

Preamble

DOI: 10.11931/guihaia.gxzw201907017

Title: Contents and Potential Ecological Risk Assessment of Heavy Metals in Soil and Siraitia grosvenorii at the Hilly Region in Longsheng County—Taking Baozeng Village as an Example

Authors: ZHANG De-Nan[1], ZHOU Long-Wu[1], DUAN Chun-Yan[2], CHEN Xia-Xia[2], HE Wen[1], TENG Qiu-Mei[1], SUN Ying-Jie[1], ZHANG Zhong-Feng[1], XU Guang-Ping[1]*

Affiliations: [1] Guangxi Institute of Botany, Guangxi Zhuang Autonomous Region and Chinese Academy of Sciences; Guangxi Key Laboratory of Plant Conservation and Restoration Ecology in Karst Terrain, Guilin 541006, China [2] College of Life Sciences, Guangxi Normal University, Guilin 541004, China

Abstract

Longsheng County is one of the three main producing areas of Siraitia grosvenorii in Guilin City. The content of heavy metals in plantation soil and fruit quality directly affects the healthy development of the S. grosvenorii industry in this region. To explore the safety of S. grosvenorii orchards in typical impoverished hilly mountainous areas of Longsheng County, this study investigated the contents of seven heavy metals (arsenic, copper, zinc, lead, cadmium, chromium, and mercury) in soil and S. grosvenorii fruits from Baozeng Village, and analyzed their potential ecological risks using the Hakanson index method. Results showed that: (1) Heavy metal contents in orchard soils (0–10 cm and 10–20 cm layers) all met the screening values for agricultural land in the national soil environmental quality standard (GB15618-2018). Specifically, the 0–10 cm layer contained 3.67, 18.00, 58.39, 17.01, 0.10, 28.57, and 0.08 mg · kg ^{1} of arsenic, copper, zinc, lead, cadmium, chromium, and mercury, respectively, while the 10–20 cm layer contained 1.93, 12.56, 21.47, 10.51, 0.04, 17.09, and 0.02 mg · kg ^{1}, respectively. (2) The overall ecological risk status of heavy metals in both soil layers fell within the slight ecological risk category, with comprehensive ecological risk indices of 105.29 and 38.96, respectively. In the 0-10 cm layer, the potential ecological risk order was mercury > cadmium > lead > copper > arsenic > zinc > chromium, with mercury and cadmium showing moderate ecological risk levels of 50.16 and 42.05, respectively, contributing 47.6% and 39.9% to the total heavy metal risk. In the 10-20 cm layer, the risk order was cadmium > mercury > copper > lead > arsenic > chromium > zinc. (3) Heavy metal contents in S. grosvenorii fruits were 0.00024, 0.273, 1.10, 0.0016, 0.00013, 0.00013, and 0.00012 mg · kg ^{1} for arsenic, copper, zinc, lead, cadmium, chromium, and mercury, respectively, all within the slight risk category. The ecological risk order in fruits was mercury > copper > cadmium > zinc > lead > arsenic > chromium, with a comprehensive ecological risk index of 0.21193, indicating virtually no ecological risk. Therefore, S. grosvenorii cultivation in Baozeng Village, a typical impoverished mountainous area in Longsheng County, meets safety and quality standards and can be promoted as a safe agricultural practice.

Keywords: soil, Siraitia grosvenorii, heavy metals, ecological risk assessment

Introduction

Longsheng County is located in northern Guangxi, in the southwestern part of the Nanling Mountain range, with low average elevation, a mild climate, abundant sunlight, and distinct seasons—providing superior climatic conditions. The area features deep soil layers with good cultivability, suitable for developing various dryland crops, particularly S. grosvenorii. As the cultivation origin center of S. grosvenorii, northern Guangxi has a history of over 300 years of folk cultivation, accounting for 95% of national planting area and output, with 90% of global S. grosvenorii production originating from this region. As both a medicinal and food resource and an important import-export commodity for northern Guangxi, S. grosvenorii quality and safety directly affect the region' s ecological industry development. Conducting soil environmental quality surveys and assessments helps advance prevention of potential soil contamination and promotes healthy, stable, and sustainable development of regional farmland ecosystems. Therefore, strengthening research on heavy metal elements in S. grosvenorii plantation areas and fruits is crucial for evaluating both fruit quality safety and production environment.

Heavy metals in the environment are characterized by wide sources, long residual toxicity, and resistance to microbial decomposition, causing serious environmental problems. They migrate and cycle through ecosystems via various pathways, ultimately entering the human body and causing significant harm. Recent domestic research on S. grosvenorii has focused on germplasm resources, ecological environments, pharmacology, cultivation techniques, chemical composition, and development/utilization. In recent years, S. grosvenorii has been gradually promoted and trialed in medium-to-high elevation hilly mountainous areas of Longsheng County, Guilin City. In Baozeng Village, Lejiang Town, a typical impoverished village, an "enterprise + research institute + farmers" cultivation model has been established. However, research on heavy metal pollution and potential ecological hazards in soil and S. grosvenorii fruits remains unclear. Therefore, this study investigates heavy metal contents in soils and fruits from Baozeng Village’ s S. grosvenorii plantations and evaluates potential ecological risks using the Hakanson index method, aiming to provide a theoretical basis for safe development of the S. grosvenorii industry in this region.

1. Study Area Overview

The study area is located in Longsheng County, northwestern Guilin City, northern Guangxi—a major S. grosvenorii production region. The total area is 2,538 km^2, with higher terrain in the east, south, and north and lower in the west, featuring a vertical elevation difference of 1,777 m between high and low altitudes, with mountains and slopes forming stepped inclines. The selected research area consists of hilly mountains with exposed bedrock, relatively poor soil, and fragile ecological conditions. It has a subtropical monsoon climate with an average annual temperature of 18-19°C, accumulated temperature 10°C of 5,064-6,383°C, annual sunshine hours of 1,237.3-1,626.4 h, and a frost-free period of 308-314 days. Rainfall is abundant, with average annual precipitation between 1,500-2,400 mm. S. grosvenorii is mainly planted on hills and slopes at 300-800 m elevation, with soils developed from carbonate rocks forming red soils composed of sandy loam and clay.

2.1 Sampling Methods

In S. grosvenorii plantations in Baozeng Village, Lejiang Town, Longsheng County, Guangxi (109°59’ 13’ ‘N, 25°50’ 14’ ’ E, elevation 523-650 m), three representative plantation plots at different altitudes were selected, each covering 1 ha. Soil samples were collected from 0-10 cm and 10-20 cm layers using the five-point sampling method, with five subsamples from the same layer combined into one composite sample (1.5 kg each). Three soil samples were collected from each plot. Soil samples were pretreated, air-dried, ground, and passed through a 0.150 mm sieve for analysis. At each soil sampling point, a 100 cm × 100 cm quadrat was established for fruit collection. Mature green fruits (90-100 days growth, with yellowing stalks and yellowish-green peel) were collected, with three fruit samples per plot (nine fruits each: three large, three medium, three small). Collected fruits were stored in 保鲜 bags, transported to the laboratory, and oven-dried at 65°C for subsequent analysis.

2.2 Testing Methods

An IRIS1000ER/S inductively coupled plasma optical emission spectrometer (Thermo Jarrell Ash Co., USA) was used to determine arsenic (As), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) contents. Operating parameters were: RF power 1,150 W, nebulizer pressure 30.06 psi (1 psi = 6.89 × 10^3 Pa), auxiliary gas flow 0.5 L · min ^{1}, peristaltic pump speed 100 r · min ^{1}, rinse time 45 s, and sample uptake 1.85 mL · min ^{1}. The instrument detection limit was <0.00001. A microwave digestion system (ETHOS1, Germany) operated at 1,000 W with the following program: ramp from 20°C to 180°C over 10 min, hold at 180°C for 20 min, then cool from 180°C to 20°C over 30 min. All reagents were analytical grade, and laboratory water was ultrapure (Elga Purelab Classic system, UK). An ER-180A analytical balance (Shimadzu, Japan) and electric thermostatic drying oven (Shanghai Experimental Instrument Factory) were used. Standard solutions for As, Cu, Zn, Pb, Cd, Cr, and Hg (from National Center for Iron and Steel Materials Testing) were prepared with 1% HNO . Samples (0.5000 g) were placed in quartz digestion vessels with 8 mL HNO and digested according to the microwave program. Blank controls were prepared simultaneously. After digestion, samples were heated to near dryness (0.5-1.0 mL), transferred to 50 mL volumetric flasks, rinsed repeatedly, and diluted to volume with ultrapure water. Element contents in soil and plant samples are expressed as mass fractions in dry matter.

2.3 Single Factor Pollution Index Method

The single factor pollution index method was used to evaluate heavy metal contamination in soil and S. grosvenorii fruits:

$$PI_i = \frac{C_i}{S_i}$$

where PI_i is the pollution index of heavy metal i at the sampling point, C_i is the measured content of heavy metal i, and S_i is the evaluation standard content for heavy metal i.

2.4 Potential Risk Assessment Method for Soil and S. grosvenorii Fruits

The potential ecological risk index method proposed by Swedish scientist Hakanson was used to evaluate soil and fruit samples. This method converts heavy metal contents into biological toxicity risks based on their release capacity and biological toxicity intensity. For multiple heavy metals, risks are summed to obtain a comprehensive index:

$$E_r^i = T_r^i \times \frac{C_s^i}{C_n^i}$$

$$RI = \sum_{i=1}^{n} E_r^i$$

where E_r^i is the potential ecological risk index for heavy metal i, T_r^i is the toxicity coefficient for heavy metal i (see Table 1) [**?**], C_s^i is the measured value, and

C_n^i is the reference value (using Guangxi soil heavy metal background values as reference, see Table 1) [?, ?, ?, ?]. RI is the comprehensive potential ecological risk index. The classification of pollution levels using Hakanson' s potential ecological risk index is shown in Table 2 [?].

2.5 Data Processing

Excel 2007 and SPSS 19 software were used for statistical analysis. Variance analysis was performed for different heavy metal pollutants, and Pearson correlation analysis was conducted for different heavy metal elements in soil.

3.1 Heavy Metal Content Analysis in S. grosvenorii Orchard Soils

The average contents of all seven heavy metals in the surveyed soil samples were far below the national agricultural land soil environmental quality standard limits (GB15618-2018), indicating that soils in Baozeng Village' s S. grosvenorii orchards met the national screening values for agricultural land. Heavy metal contents in 0-20 cm soils decreased in the order: zinc > chromium > copper > lead > arsenic > cadmium > mercury (Table 3), with all sampling points meeting cultivation requirements.

Average heavy metal contents in the 0-10 cm soil layer of Baozeng Village orchards were lower than those in agricultural soils of northeastern Guangxi, and all elements except mercury were lower than background values for the Xijiang River basin and national soil background values. Based on northeastern Guangxi agricultural soil values, the data fall within normal ranges, indicating superior soil quality in the study area. Average heavy metal contents in the 10-20 cm layer were lower than northeastern Guangxi agricultural soils, Xijiang River basin background values, and national soil background values, with heavy metal contents decreasing with soil depth.

3.2 Heavy Metal Content Analysis in S. grosvenorii Fruits

As shown in Table 4 , heavy metal contents in S. grosvenorii fruits from the study area met the national food contaminant limit standards, with arsenic, lead, cadmium, chromium, and mercury contents nearly zero. The contents of arsenic, copper, lead, cadmium, and mercury in fruits fully complied with the Green Industry Standard for Medicinal Plants (WM/T2-2004).

3.3 Ecological Risk Analysis of Heavy Metals in Orchard Soils and Fruits

Table 5 shows that the ecological risk status of heavy metals in surface soil (0-10 cm) of S. grosvenorii orchards in Longsheng' s hilly region was generally at the slight ecological risk level. The ecological risk order for the seven heavy metals was mercury > cadmium > lead > copper > arsenic > zinc > chromium. Mercury showed the highest ecological risk value (50.16), reaching moderate ecological risk intensity, followed by cadmium (42.05), also reaching moderate ecological risk. Mercury and cadmium contributed 47.6% and 39.9%, respectively, to the total heavy metal ecological risk. The higher risks for mercury and cadmium are related to their higher biological toxicity and recent accumulation rates.

In the 10-20 cm soil layer, heavy metal ecological risk status was at the slight ecological risk level, with the risk order: cadmium > mercury > copper > lead > arsenic > chromium > zinc. In S. grosvenorii fruits, heavy metal ecological risk was at the slight risk level, with the order: mercury > copper > cadmium > zinc > lead > arsenic > chromium. The ecological risk values were extremely low, indicating virtually no risk.

3.4 Correlation Analysis of Heavy Metals in Orchard Soils

Correlation analysis showed no significant correlation between cadmium and chromium (P = 0.527, r = 0.038), but good correlation between cadmium and zinc (P = 0.839, r = 0.002) and between arsenic and mercury (P = 0.635, r = 0.001). These correlations suggest certain common sources for these heavy metals and metalloids.

4 Discussion and Conclusion

In Baozeng Village' s S. grosvenorii orchard soils (0–10 cm), arsenic, copper, zinc, and chromium contents showed no significant changes relative to background values, while zinc, cadmium, and mercury contents increased to 1.1 times background values, though still below national agricultural land screening standards. Mercury content was lower than that in agricultural soils of northeastern Guangxi measured by Zheng (1993), likely due to the absence of mercury pollution sources in this remote, impoverished mountainous area with uncontaminated soils.

The seven heavy metal contents in S. grosvenorii fruits from the study area were far below national food contaminant limits, with arsenic, lead, cadmium, chromium, and mercury contents approaching instrument detection limits. Copper and zinc were only 0.0273 and 0.022 times national standards, respectively, similar to results from other studies in Longsheng County. Compared with S. grosvenorii fruits from Lingui and Yongfu (also major production areas in northern Guangxi), the arsenic, copper, lead, cadmium, and mercury contents in this study were only 1/1000, 1/20, 1/1000, 1/2000, and 1/100 of those in the other two regions, respectively. These values fully comply with the Green Industry Standard for Medicinal Plants (WM/T2-2004), being only 1/10,000, 1/100, 3/10,000, 1/2,500, and 3/2,500 of the standard values. This demonstrates that S. grosvenorii from the study area is greener and safer, and that cultivation and industry development in this region is safe and feasible.

In summary, heavy metal contents in S. grosvenorii orchard soils from Baozeng Village, a typical impoverished mountainous area in Longsheng, are far below national agricultural land soil environmental quality standard limits, meeting national screening values. The ecological risk status of heavy metals in surface soil (0–10 cm) was generally at the slight ecological risk level, with the risk order: mercury > cadmium > lead > copper > arsenic > zinc > chromium. Mercury and cadmium showed higher ecological risks, contributing 47.6% and 39.9% to total risk and reaching moderate ecological risk levels. In the 10–20 cm soil layer, ecological risk was at the slight level, with the order: cadmium > mercury > copper > lead > arsenic > chromium > zinc. In S. grosvenorii fruits, ecological risk was at the slight level, with the order: mercury > copper > cadmium > zinc > lead > arsenic > chromium, representing virtually no ecological risk and ensuring safe medicinal and food use. Therefore, we recommend S. grosvenorii as a priority green industry for cultivation and promotion in typical hilly mountainous areas like Baozeng Village and surrounding impoverished regions.

Acknowledgments: We thank Cheng Guixia, Liu Jianchun, Jiang Yulong, and others for assistance with sample analysis.

References

BAI XD, ZHAO H, TANG GS, et al., 2009. Analysis of meteorological condition influence on growth of Siraitia grosvenorii [J]. Acta Agric Jiangxi, 21(7): 113-116.

CHANG FS, LI HQ, 1981. Preliminary investigation and study on raw plants, resources and ecological environment of Siraitia grosvenorii [J]. Chin Pharm J, 16(4): 161-163.

CHEN JS, CAO LM, SU XZ, et al., 2019. Ethnobotany knowledge of traditional medicinal plants among hong-yao in Longsheng, Guangxi [J]. Guihaia, 39(3): 375-385.

CHEN QB, SHEN ZS, WEI ZB, et al., 2005a. The study on the pharmacological function of stimulate circulation to end stasis of flavone from Siraitia grosvenorii [J]. Guangxi Sci, 12(4): 316-319.

CHEN QB, YANG JX, CHENG ZQ, et al., 2005b. The determination of total flavonoids in Momordica grosvenorii leaf by RP-HPLC [J]. Guangxi Sci, 12(1): 43-45.

CHEN WP, YANG Y, XIE T, et al., 2018. Challenges and countermeasures for heavy metal pollution control in farmlands of China [J]. Acta Pedol Sin, 55(2): 261-272.

CHENG F, 2014. Researchs on mechanical properties and curing measures of rock-soil invaded by heavy metals [D]. Changsha: Central South University.

DING ZH, JIA HW, LIU CE, 2006. Pollution and assessment of heavy metals in Huangpu river sediments [J]. Environ Sci Technol, 29(2): 64-65.

Environmental monitoring of China, 1990. Background values of soil elements in China [M]. Beijing: China Environmental Science Press: 330-382.

FAN CB, 2008. Preliminary report on cultivating Siraitia grosvenorii in the flat [J]. Guangxi Trop Agric, (1): 6-7.

FAN CX, ZHU YX, 2002. Characteristics of pollution of heavy metals in the sediments of Yilihe River, Taihu basin [J]. J Lake Sci, 14(3): 235-241.

HAKANSON L, 1980. An ecological risk index for aquatic pollution control—A sedimentological approach [J]. Water Res, 14(8): 975-1001.

JIA ZB, ZHAO ZJ, YANG XM, et al., 2001. Pollution and assessment of heavy metals in Yangyong River, Maozhou River and Dongbao River sediments, Shenzhen [J]. Environ Chem, 20(3): 212-219.

LI F, 2007. The research on maximum limited standards for contaminants in Siraitia grosvenorii [D]. Changsha: Central South University of Forestry Science and Technology.

LI F, JIANG XJ, JIANG SY, et al., 2008. The successful culture of seedless Siraitia grosvenorii [J]. Guihaia, 28(6): 727.

LI S, WANG HS, ZHANG GY, 2003. Chemical constituent in seed of Siraitia grosvenorii [J]. Guangxi Med J, 25(5): 850-852.

LING NG, 2010. Analysis of heavy metal content in different farmland soils in guangxi [J]. J Agric Resourc Environ, 27(4): 91-94.

LIU JL, LI DP, HUANG YL, 2007. Determination of mogrol glycocides and mogroside V content in the fresh fruit of some Siraitia grosvenorii varieties from different places in North Guangxi [J]. Guihaia, 27(2): 281-284.

LOIZIDOUS M, HARALAMBOUS KJ, SAKELLARIDES PO, 1991. Chemical treatment of sediments contaminated with heavy metals [C] // 8th International Conference Heavy Metals in the Environment, Edinburgh.

PENG YT, TANG SQ, LI BL, et al., 2005. Genetic diversity of Siraitia grosvenorii detected by ISSR markers [J]. Biodivers Sci, 13(1): 36-42.

RAN HX, ZHOU P, XIE MQ, et al., 2019. Heavy metal pollution and control in soil—taking Guangxi as an example [J]. Environ Dev, 31(4): 23-24.

SAVVIDES C, PAPADOPOULOS A, HARALAMBOUS KJ, et al., 1995. Sea sediments contaminated with heavy metals: metal speciation and removal [J]. Wat Sci Technol, 32(9-10): 65-73.

SHEN YY, ZHOU YH, CHEN HSD, et al., 2012. Determinations of trace elements and amino acids in Thalictrum baicalense Turcz [J]. Guangdong Agric Sci, 39(14): 116-118.

WANG FP, SONG B, ZHOU L, et al., 2018. Redistribution of heavy metal background in soil of Xijiang river basin in Guangxi [J]. Acta Sci Circumst, 38(9): 3695-3702.

WANG X, HAN BP, 2006. Heavy metal pollution in bottom sediments of abandoned Yellow River, Xuzhou [J]. Environ Sci Technol, 29(11): 1-2, 38.

WEN XH, 1993. Sediment quality criteria for heavy metals [J]. Environ Chem, 12(5): 334-341.

XU ZQ, NI SJ, TUO XG, et al., 2008. Calculation of Heavy metals' toxicity coefficient in the evaluation of potential ecological risk index [J]. Environ Sci Technol, 31(2): 112-115.

XU ZQ, NI SJ, ZHANG CJ, et al., 2004a. Assessment on heavy metals in the sediments of Jinsha River in Panzhihua area by pollution load index [J]. Sichuan Environ, 23(3): 67-67.

XU ZQ, NI SJ, ZHANG CJ, et al., 2004b. The distribution characteristics and evaluation of heavy metals of Jinsha River sediments in Panzhihua [J]. Comput Techniqu Geophysical Geochemical Expl, 26(3): 252-255.

YANG SX, LI MS, LI Y, et al., 2006. Study on heavy metal pollution and ecological restoration of soil and plant in Pingle manganese mine area of Guangxi [J]. Min Safety & Environ Prot, 33(1): 21-23.

ZHANG L, QIN YW, ZHENG BH, et al., 2011. Distribution and pollution assessment of heavy metals in sediments from typical areas in the Bohai Sea [J]. Acta Sci Circumst, 31(8): 1676-1684.

ZENG QG, 2012. Agro-Geology of Siraitia grosvenorii in karst peek-cluster ecosystem in north Guilin, Guangxi [D]. Chengdu: Chengdu University of Technology.

ZHAO HF, YAN HY, WANG X, et al., 2016. Mercury concentrations and potential risk assessment of paddy soil in south China [J]. Asian J Ecotoxicol, 11(6): 252-258.

ZHENG W, 1993. Investigation on background values of several heavy metal elements in agricultural soil environment in northeast Guangxi [J]. J Ecol Rural Environ, (4): 39-42.

ZHOU XX, SONG JS, 2004. Study on pharmacology of Momordica grosvenorii extracts [J]. Study J Trad Chin Med, 22(9): 1723-1724.

ZHU ZL, JIN JY, 2013. Fertilizer use and food security in China [J]. Plant Nutr Fert Sci, 19(2): 259-273.

Note: Figure translations are in progress. See original paper for figures.