Evaluation suitability of Guanzhong land for green and selenium-rich planting

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Abstract. To carry out the suitability evaluation of green and selenium (Se)-rich planting in Guanzhong area, 74 maize plant samples and 74 rhizosphere soil samples were collected. Our results showed that all soils in the Guanzhong area were clean and pollution-free, but only cinnamon soil and alluvial soil can be divided into green Se-rich land. Moreover, there is safe and no heavy metal exceeded standard in maize seed samples in the Guanzhong area, but only Se content of maize seeds grown in cinnamon soil and alluvial soil reached the Se content standard of Shaanxi Se-rich food (> 0.05 mg/kg) according to soil environmental quality standard, the national standards for food safety, natural selenium-rich land demarcation and identification, and Se-rich food standard of Shaanxi province. These results indicated that cinnamon soil and alluvial soil in the Guanzhong area was very suitable for planting natural, green and safe Se-rich crops.

1. Introduction

Selenium (Se) is an important trace element in the ecological environment [1]. At the same time, as a necessary trace element for human and animals, it has a wide range of biological functions, especially in enhancing the body immunity, preventing cardiovascular, Keshan and Kashin-Beck disease, cancer-fighting, antioxidant and anti-aging [1-2]. With people’s understanding of Se, Se-rich agricultural products are gradually selling well and thus the added value of agricultural products are greatly increased [3-6]. Researches show that Se in plants mainly comes from the soil and then enters the human body through the food chain [7]. Thus, soil Se content affects the absorption and accumulation of Se in crops and ultimately affects human health [7]. Therefore, it is of great significance to study soil environments, and characteristics of Se content in soils and crops.

Guanzhong area of Shaanxi Province is an important commodity grain production area in China, with a long history of agricultural production and abundant agricultural specialty resources [8]. Affected by the continental monsoon climate, the region has clear four seasons and sufficient sunshine. The annual average temperature is 12-13°C, and the annual average precipitation is 550-750 mm. The soil types in this area are diverse, including 12 soil types, mainly cinnamon soil and loessial soil, as well as alluvial soil, black loessial soil, coarse-grained soil, fluvo-aquic soil, red soil, aeolian sandy soil, paddy soil, swamp soil, brown soil and stone soil [8]. Among them, the area of cinnamon soil is 14980.25 km², accounting for 37.94% of the total area of the region [8]. The cinnamon soil is rich in minerals and has high fertility, and is a high-quality soil suitable for agricultural development [8]. Therefore, the objective of this study is to carry out sustainable evaluation of green and Se-rich planting in Guanzhong area, and this will provide scientific basis for the exploitation and utilization of
Se resources and the adjustment of planting structure in Shaanxi Province, and is of great significance for improving people’s health level and social and economic development.

2. Research method and design

2.1. Plant and rhizosphere soil sample collection
In the Guanzhong area, maize seed and different soil types including fluvo-aquic soil, aeolian sandy soil, cinnamon soil, black loessial soil, red soil, alluvial soil was selected as the research objects, and samples of maize and rhizosphere soil were collected. The principle of sampling is to sample plants from different soil types and avoid plants that are too large or too small, that suffer from diseases, pests or mechanical damage, and that are on the bank of the field and along the road. The weight of maize seed samples collected was greater than 500 g, while the weight of maize rhizosphere soils collected at the same point was 1 kg. A total of 74 maize seed and rhizosphere soil samples were collected (Figure 1). The sample size distribution is shown in the Table 1.

2.2. Sample treatment and analysis
Soil samples were naturally air-dried, crushed agglomerates with wooden sticks, passed through a 20-mesh nylon sieve, and sent to the laboratory for analysis. An appropriate amount maize seeds were first soaked in nitric acid overnight, then added hydrogen peroxide and put in the microwave for 3-4 hours of digestion, and then diluted to a certain volume for analysis. Soil pH was analyzed by pH meter, and the ratio of soil to water was 1:2.5. Soil and maize seed As, Cd, Cr, Cu, Hg, Ni, Pb and Zn were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Soil Se and maize seed Se were determined by atomic fluorescence spectrometry (AFS).

The sample analysis and testing are undertaken by the Xi'an Mineral Resources Supervision and Testing Center of the Ministry of Land and Resources. During the test, national first-level standards

![Figure 1. Soil type distribution map of Guanzhong, Shaanxi.](image)

Note: Black dots represent the maize sampling points
were randomly added to control the analysis quality. The reporting rate of all samples was 100%, and the qualification rate of accuracy and precision monitoring sample was over 98%.

2.3. Statistical analysis

Date statistics and analyses were processed by Excel 2013 and SPSS18.0 software. All data are expressed as mean ± standard error (SE).

3. Results and analysis

The risk screening values and the risk intervention values for soil contamination of agricultural land specified in the soil environmental quality standard “Risk control standard for soil contamination of agricultural land” (GB15618-2018) were used as risk levels in measuring heavy metal content in the soil. In this study, the pH values of different types of soil in Guanzhong all were greater than 7.5 (Figure 2). Moreover, the contents of various pollutants in different types of soil in Guanzhong all were significantly lower than the risk screening values and the risk intervention values shown in Table 2, indicating that soils in the Guanzhong area were clean and pollution-free (Table 3).

Table 2. Risk screening values and risk intervention values for soil contamination of agricultural land when soil pH > 7.5.

| Pollutant item | Risk screening values (mg/kg) | Risk intervention values (mg/kg) |
|----------------|------------------------------|---------------------------------|
| Cd Paddy field | 0.8                          | 4                               |
|                | Other                        | 0.6                             | 4                               |
| Hg Paddy field | 1.0                          | 6                               |
|                | Other                        | 3.4                             | 6                               |
| As Paddy field | 20                           | 100                             |
|                | Other                        | 25                              | 100                             |
| Pb Paddy field | 240                          | 1000                            |
|                | Other                        | 170                             | 1000                            |
| Cr Paddy field | 350                          | 1300                            |
|                | Other                        | 250                             | 1300                            |
| Cu Paddy field | 200                          | -                               |
|                | Other                        | 100                             | -                               |
| Ni             | 190                          | -                               |
| Zn             | 300                          | -                               |

"-" indicates no standard limitation.

Figure 2. PH value of different types of soils.
Table 3. Element content (mg/kg) of different soil types.

| Soil types          | As   | Cd   | Cr   | Cu   | Hg   | Ni   | Pb   | Zn   |
|---------------------|------|------|------|------|------|------|------|------|
| fluvo-aquic soil    | 12.61±0.54 | 0.24±0.01 | 65.46±1.48 | 25.18±1.35 | 0.12±0.05 | 32.81±1.50 | 32.01±6.83 | 69.83±2.62 |
| aeolian sandy soil  | 10.59±2.59 | 0.19±0.03 | 53.51±9.07 | 21.15±4.33 | 0.04±0.01 | 25.39±7.12 | 21.81±2.78 | 57.46±11.9 |
| cinnamon soil       | 13.00±0.53 | 0.22±0.01 | 68.24±2.24 | 25.49±1.14 | 0.09±0.01 | 33.27±1.51 | 25.55±1.12 | 73.30±2.93 |
| black loessial soil | 14.58±0.38 | 0.18±0.01 | 71.49±0.97 | 26.88±0.98 | 0.06±0.01 | 37.57±0.78 | 24.56±0.91 | 72.04±1.61 |
| red soil            | 12.64±0.77 | 0.16±0.01 | 63.35±3.12 | 24.27±1.46 | 0.04±0.01 | 31.08±2.39 | 22.34±0.88 | 69.43±4.48 |
| alluvial soil       | 11.45±1.42 | 0.22±0.04 | 60.32±6.05 | 24.91±3.08 | 0.08±0.03 | 28.81±4.27 | 24.31±2.22 | 68.54±8.50 |
| Guanzhong total     | 12.61±0.38 | 0.22±0.01 | 65.33±1.52 | 25.01±0.77 | 0.09±0.01 | 32.12±1.09 | 26.30±1.69 | 70.29±2.00 |

According to the standard limits of heavy metal content in grain given by the National standards for food safety “Limit of pollutants in food” (GB 2762-2017) (Table 4), the safety of maize seeds grown in different soil types in Guanzhong area was evaluated. It was found that the contents of various pollutants in maize seeds in different soil types all were significantly lower (Table 5) than the standard limits shown in Table 4, indicating that there is safe and no heavy metal exceeded standard in maize grown in the Guanzhong area (Table 5).

Table 4. Quality evaluation index and standard limitation for cereal.

| As (mg/kg) | Cd (mg/kg) | Cr (mg/kg) | Cu (mg/kg) | Ni (mg/kg) | Pb (mg/kg) | Zn (mg/kg) | Hg (mg/kg) |
|------------|------------|------------|------------|------------|------------|------------|------------|
| cereal     | 0.5        | 0.1        | 1.0        | -          | 0.2        | -          | 0.02       |

*"-"indicates no standard limitation.*

Table 5. Element content (mg/kg) of maize seed in different soil types.

| Soil types          | As     | Cd     | Cr     | Cu     | Hg     | Ni     | Pb     | Zn     |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| fluvo-aquic soil    | 0.020±0.00 | 0.003±0.00 | 0.078±0.00 | 1.489±0.09 | 0.002±0.00 | 0.237±0.03 | 0.036±0.00 | 17.24±0.41 |
| aeolian sandy soil  | 0.023±0.00 | 0.004±0.00 | 0.077±0.00 | 1.420±0.09 | 0.002±0.00 | 0.197±0.04 | 0.034±0.00 | 16.82±0.72 |
| cinnamon soil       | 0.022±0.00 | 0.003±0.00 | 0.074±0.00 | 1.443±0.06 | 0.002±0.00 | 0.159±0.01 | 0.037±0.00 | 15.97±0.46 |
| black loessial soil | 0.027±0.01 | 0.002±0.00 | 0.071±0.00 | 1.030±0.07 | 0.002±0.00 | 0.200±0.02 | 0.040±0.01 | 14.88±1.15 |
| red soil            | 0.020±0.00 | 0.002±0.00 | 0.066±0.00 | 0.966±0.06 | 0.002±0.00 | 0.157±0.01 | 0.028±0.00 | 12.11±1.01 |
| alluvial soil       | 0.023±0.00 | 0.004±0.00 | 0.073±0.00 | 1.688±0.14 | 0.002±0.00 | 0.164±0.04 | 0.040±0.00 | 17.62±0.66 |
| Guanzhong total     | 0.022±0.00 | 0.003±0.00 | 0.074±0.00 | 1.421±0.04 | 0.002±0.00 | 0.183±0.01 | 0.036±0.00 | 16.24±0.30 |

Figure 3. Se content of different soil types.
According to the demarcation of Se-rich land in “Natural selenium-rich land demarcation and identification” (Trial) (DD 2019-10), land type with soil pH > 7.5, soil Se content greater than or equal to 0.3 mg/kg, and soil Cd, Hg, As, Pb and Cr content met the standard requirements of GB 15618 was divided into green Se-rich land. As shown in Figure 3, the Se content of cinnamon soil and alluvial soil was significantly higher than 0.3 mg/kg, and the contents of Cd, Hg, As, Pb and Cr in the soil all met the standard requirements of GB 15618 (Table 3). Therefore, the cinnamon soil and alluvial soil can be divided into green Se-rich land.

Referred to the definition of Se-rich grains in the Se-rich food standard of Shaanxi province “Standard for Selenium Content in Selenium-enriched/selenium-containing Foods and Related Products” (DB 61/T 556-2018), Se content of maize seeds grown in cinnamon soil and alluvial soil reached the Se content standard of Shaanxi Se-rich food (> 0.05 mg/kg), but Se content of maize seeds grown in fluvo-aquic soil, aeolian sandy soil, black loessial soil and red soil was lower than that of Shaanxi Se-rich food (> 0.05 mg/kg) (Figure 4).

![Figure 4. Se content of maize seed in different soil types.](image-url)

4. Discussions
As an essential trace element, Se has attracted much attention for its ability to promote animal immune function, stimulate the production of proteins and antibodies, as well as its special anti-oxidation, anti-cancer and detoxification [1-2]. With the continuous improvement of people’s living standards, the gradual popularization of Se function and the people’s increasing awareness of nutrition and health care, China have set off a boom in developing Se-rich industries and producing Se-rich agricultural products [5]. Finley and Davis [9] also believe that organic Se is a reliable and effective source of Se compared to inorganic Se compounds, and using plant organic Se to supplement Se has become a research hotspot in functional foods. Soil is the basic source of Se in the soil-plant-human and animal ecosystems, and regional soil Se content is of great significance for Se levels in agricultural products and biological health [7].

In this study, our results showed that all soils in the Guanzhong area were clean and pollution-free, but only cinnamon soil and alluvial soil can be divided into green Se-rich land; moreover, there is safe and no heavy metal exceeded standard in maize grown in the Guanzhong area, but only Se content of maize seeds grown in cinnamon soil and alluvial soil reached the Se content standard of Shaanxi Se-rich food (> 0.05 mg/kg), indicating cinnamon soil and alluvial soil was very suitable for planting natural, green and safe Se-rich maize. Consistent with our findings, through studying the characteristics of Se content in soil and crops in Sanyuan-Yanliang area of Guanzhong, Ren et al. [10]
found that this investigation area has unique advantages in developing natural, green and safe Se-rich crops. Moreover, Ren et al. [8] systematically studied the distribution characteristics and influencing factors of soil Se in Guanzhong area by using deep and topsoil data from multi-objective regional geochemical survey in Shaanxi Province. It was found that the Se content in the topsoil of Guanzhong area ranged from 0.034 mg/kg to 2.628 mg/kg, with an average Se content of 0.174 mg/kg. The Se-rich soil was 8245.12 km², and among them, cinnamon soil, alluvial soil, and paddy soil have potential to develop Se-rich products. Therefore, the Guanzhong land was suitable for planting green and safe Se-rich crops.

5. Conclusions
In this study, the cinnamon soil and alluvial soil in the Guanzhong area were evaluated as clean and pollution-free and therefore green Se-rich land. Moreover, there is safe and no heavy metal exceeded standard in maize grown in cinnamon soil and alluvial soil, and Se content of maize seeds grown in cinnamon soil and alluvial soil reached the Se content standard of Shaanxi Se-rich food (> 0.05 mg/kg). In conclusion, cinnamon soil and alluvial soil in the Guanzhong area was very suitable for planting natural, green and safe Se-rich crops.

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