agriculture

MDPI

Article

Screening of Maize Varieties with High Biomass and Low Accumulation of Pb and Cd around Lead and Zinc Smelting Enterprises: Field Experiment

Peiyi Zeng [1,2,3], Shujuan He [2,3], Liping He [2,3], Muqing Yang [2,3], Xian Zhu [2,3] and Min Wu [1,*]

[1] Faculty of Environmental Science and Engineering, Kunming University of Science and Technology, Kunming 650500, China; peiyizeng529@163.com
[2] Yunan Research Academy of Eco-environmental Sciences, Kunming 650034, China; ynhsj1989@126.com (S.H.); helipingsoil1974@163.com (L.H.); yangmuqing0414@163.com (M.Y.); zhuxianyunduo@163.com (X.Z.)
[3] Yunnan National Engineering Research Center for Control & Treatment of Heavy Metal Pollution, Kunming 650034, China
* Correspondence: minwup@kust.edu.cn

Abstract: In the long-term production process of lead and zinc smelting enterprises, atmospheric subsidence leads to the accumulation of heavy metals in surrounding farmland, which poses a serious threat to the growth of crops and food safety. Given the knowledge that heavy metal pollution in cultivated land does not support treatment and restoration, determining how to ensure the quality and safety of agricultural products is the main problem facing the agricultural industry at present. Previous studies have mainly focused on the low accumulation of heavy metals in maize varieties, while the removal of heavy metals from soil through high biomass has been studied less. In order to identify the maize varieties that demonstrate high removal and low accumulation of heavy metals, 29 maize varieties were planted in soil contaminated with lead (Pb) and cadmium (Cd), and the growth status of the maize varieties and the absorption and transport of Pb and Cd by different tissues were studied. The results showed that heavy metals had the least effect on the growth of the Longhuangbai3, Jinqiuyu 35, Jinyi 418, and Qiuqing 88 varieties, and the content of Pb and Cd in maize varieties was in the order leaf > stem > root > grain. It was found that soil remediation and safe production can be taken into account in the results of the Qiuqing 88 (Pb, Cd), Fengdeng 2025 (Cd), and Yayu 719 (Pb, Cd) varieties. Moreover, the Xinzhongyu 801 (Cd) and Longdan 1701 (Pb) varieties demonstrated high metal accumulation in the edible part, which poses a potential risk to human health; thus, they are not recommended for local cultivation.

Keywords: heavy metals; high biomass; low accumulation; maize variety screening

check for updates

Citation: Zeng, P.; He, S.; He, L.; Yang, M.; Zhu, X.; Wu, M. Screening of Maize Varieties with High Biomass and Low Accumulation of Pb and Cd around Lead and Zinc Smelting Enterprises: Field Experiment. *Agriculture* **2024**, *14*, 423. https://doi.org/10.3390/agriculture14030423

Academic Editors: Isabel Lara and Claudia E. Moggia

Received: 9 February 2024
Revised: 3 March 2024
Accepted: 4 March 2024
Published: 6 March 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Heavy metals are common soil pollutants [1]. According to the Bulletin of Soil Environmental Quality, the overall situation of the soil environment in China is not optimistic, and soil pollution is relatively serious in some areas. The highest rate of polluted points exceeding the standard of cultivated land is 19.4%, and the severely polluted points account for 1.1% [2]. The impact of a cultivated soil environment on food safety and human health has gradually attracted people's attention. In recent years, a significant amount of relevant research work has been carried out, mainly focusing on the distribution characteristics of heavy metals in soil and crops [3–5]. This study revealed that long-term wastewater use for irrigation results in heavy metal accumulation in soils and bioaccumulation in plants beyond maximum permissible limits (MPLs) for both human and livestock consumption [6]. Leafy vegetables have shown a greater accumulation of metals than fruity vegetables [7], and the edible portion of a crop that accumulates heavy metals poses a risk to human health [8–12]. The treatment and restoration of cultivated soil, called phytoremediation, is an environmentally friendly and economically feasible technique used for reclamation of an environment contaminated with toxic heavy metals [13] and the safe utilization of technology [14].

Due to the exploitation and utilization of mineral resources and other reasons, the soil pollution in some areas of Yunnan province is very heavy, with cadmium, arsenic, and other heavy metals being the main pollutants. Therefore, the prevention and control of soil pollution is a serious issue. Given that the state does not currently support the treatment and restoration of contaminated soil in agricultural land, how to achieve the safe use of more than 572,666.67 hm^2 of contaminated farmland is a severe challenge faced by Yunnan province. At present, the technology for the safe utilization of polluted cultivated land is mainly agronomic regulation, including lime regulation, optimal fertilization, variety adjustment, water regulation, leaf-area regulation, deep plowing, and so on. Eventually, the safe utilization and treatment of polluted farmland in China should be carried out simultaneously to reduce the total amount of heavy metals in the soil while ensuring the safety of agricultural products. Lime regulation, optimal fertilization, water regulation, leaf-surface regulation, deep plowing, and other measures can only ensure the quality and safety of agricultural products, but these measures cannot achieve the purpose of removing heavy metals in the soil. The selection of plant varieties with low heavy metal contents in edible parts and high heavy metal contents and high biomass in other parts is one of the new directions for the safe utilization, treatment, and restoration of agricultural land in the future. The risk-screening values for Cd and Pb soil contamination of agricultural land are 0.3 mg/kg and 90 mg/kg. The risk intervention values for Cd and Pb soil contamination of agricultural land are 2.0 mg/kg and 500 mg/kg. The permissible limit of Cd and Pb in the edible part of a plant is 0.1 mg/kg and 0.2 mg/kg [15].

Seven cultivars had lower Cd content in grains by 24.76–47.48% than the high Cd cultivar. The cultivar LH11 was an excellent candidate for the safe utilization of polluted farmland [16]. Screening for rice germplasm with low Cd accumulation in grains is the best strategy for safe rice production in China [17]. Xu et al. found differences in cadmium accumulation among different cereal varieties in karst areas. Five rice and maize varieties with low cadmium accumulation were separately screened [18]. The above studies focused on the screening of low-accumulation varieties and only focused on the heavy metal contents of edible parts of crops and the mechanism of heavy metal detoxification of low-accumulation varieties. However, the content of heavy metals in plants increases with the increase in the concentration of heavy metals in soil, and the concentration distribution varies greatly among different plant organs. Compared with those of leaves, stems, and roots, the heavy metal contents of the edible parts of low-accumulation plant varieties are generally lower [19]. Ningke Yang et al. [20] and Yan Zha et al. [21] selected rice varieties with low contents of Cd, As, and Pb in edible parts and high contents in other parts through field experiments. A few of these studies focused on crop biomass when selecting low-accumulation varieties. Up to now, it has been rare for the content of heavy metals in edible plant parts to be low while the content of heavy metals in other parts is high and the biomass is high.

In this study, the distribution characteristics of Pb and Cd in different parts of maize (roots, stems, leaves, and grains) were studied; varieties with low metal accumulation in grain, medium and high metal accumulation in other parts, and high stem and leaf biomass were selected. These varieties can be directly planted in the soil of areas with moderate and mild heavy metal pollution, and their edible parts have low metal accumulation, which meets the national food safety standards. At the same time, maize varieties with lower stems and leaves and higher biomass can be used as good raw materials for biochar preparation, achieving better economic value, reducing the amount of agricultural waste, improving the comprehensive utilization rate of agricultural waste, and having good environmental benefits. The research results can provide a scientific basis for agricultural production and the safe use of cultivated soil in medium and mild metal-polluted soil.

2. Materials and Methods

2.1. Materials

2.1.1. Experimental Site

The experimental site is located in the southwest of Yunnan province, with geographical coordinates of 22°01″~23°16″ north latitude and 99°29″~100°35″ east longitude. The sewage and waste gas discharged by the enterprise in the process of lead and zinc smelting has a certain impact on the soil environmental quality of agricultural land around the factory. The experimental field is within 5 km of the company, which is characterized by the typical heavy metal pollution caused by atmospheric subsidence. A total of 438 soil samples were collected in the experimental base, and the soil nutrient indexes and contents of 8 heavy metals were analyzed. The physical and chemical properties and heavy metal contents of the tested soil samples are shown in Table 1. The soil pH is 4.3–6.5, organic matter content is 1.0–4.8%, Pb content is 2.3–7761 mg/kg, and Cd content is 0.1–139 mg/kg.

Table 1. Physical and chemical properties and heavy metal contents of soil tested.

Properties and Contents	Maximum Value	Minimum Value	Mean Value
pH	6.5	4.3	5.3
Organic matter (%)	4.8	1.0	2.9
Total nitrogen (N) (mg/kg)	1810	28.9	920
Total phosphorus (P) (mg/kg)	3730	659	1582.6
Available phosphorus (mg/kg)	37.8	6.2	20.7
Rapidly available potassium (mg/kg)	240	50.6	126.8
Cation exchange capacity (cmol/kg)	27.5	3.6	11.4
Total potassium (mg/kg)	27.2	6.9	16.0
Hg (mg/kg)	4.1	0.003	0.3
As (mg/kg)	303	0.3	20.4
Pb (mg/kg)	7761	2.3	367.8
Cu (mg/kg)	266	3.0	41.0
Ni (mg/kg)	672	3.0	49.7
Zn (mg/kg)	5490	18.0	266.1
Cd (mg/kg)	139	0.1	5.1
Cr (mg/kg)	498	1.0	116.2

2.1.2. Maize Varieties

According to the production table of main rural products in the study region in 2020, combined with the results of field surveys and personnel interviews, the main crops planted in this region are maize, sugarcane, and rice. In combination with the local main crops and farmers' planting habits and planting intentions, it was determined to select maize as the main crop in which to screen varieties with low accumulation and high biomass.

According to the main varieties in the project area and the low-accumulation maize varieties screened by existing cases, combined with the environmental characteristics and pollution characteristics of the project area, the selection of maize varieties was carried out. The details are provided in Table 2.

In summary, combined with the maize varieties sold in the study area in 2022, the final selection of maize varieties was as follows: Fengdeng 2025, Hongdan 6, Huidan 936, Jinqiuyu 35, Jinqiuyu 755, Jinyiyu 418, Jinyu 108, Jingdian 8, Kangyu 8, Kenyu 1505, Kongyu 829, Longbai 1, Longdan 1604, Longdan 1701, Longhuangbai 3, Longrui 3869, Longyu 1708, Ludan 12, Qinrui 3817, Qinrui 47, Qiuqing 88, Shangshan 2012, Shangyu 3899, Tianyan 29, Tianyan 31, Wugu 1790, Wugu 3861, Xinzhongyu 801, and Yayu 719.

Table 2. Selection of maize varieties.

Serial Number	Variety Origin	Varieties	Quantity (PCS)	Environmental Characteristics	Pollution Characteristics
1	Research on the main varieties provided by the regional agricultural technology extension center in the past 3 years	Hongdan 6, Lushan 12, Jinyi 418, Xikang 18, Kangnong 2, Dika 7, Shangshan 2012, Wugu 1790, Zhengda 615, Wugu 3861, Longbai 1, Xianda 901, Longdan 1604, Longyu 1708, Yaoyu 4126, Ruishan 26, Dingdan 6789, Zhengda 719	18	It is 1600~2090 m above sea level and belongs to the subtropical mountain monsoon climate. The soil type is mainly red and red soil argillaceous rock. The soil pH value is 3.92~8.09, and the soil is generally acidic	Mercury, arsenic, lead, copper, nickel, zinc, chromium, and cadmium; a total of 8 heavy metals in the regional agricultural land exceeded the standard, and the main pollutants were cadmium and lead.
2	Site survey, the main varieties sold in local shops	Qinrui 47, Qinrui 119, Qinrui 3817, Jixiang Jade 2199, Jingdian 8, Qingqing 9, Qingqing 515, Tianyan 8, Tianyan 29, Tianyan 31, Kebei 1409, Qiuqing 1, Qiuqing 88, Funong jade 1, Longrui 3869, Ziyu 88, Kangyu 8, Yiyu 8, Yayu 719, Yayu 1281, Jindan 208, Kenyu 1505, Jinyu 98, Jinyu 108, Shangyu 3899, Huizan 936, Xinzhongyu 801, Kongyu 829, Dandan 908, Kebei 1409, Lushan 12, Jinyi 418, Fengdeng 2025, Hongshan 6, Xikang 18, Kangnong 2, Dicka 007, Shangshan 2012, Shangshan 3721, Shangshan 365, Wugu 1790, Zhengda 615, Wugu 3861, Longbai 1, Xianda 901, Longdan 1604, Longdan 1609, Longdan 1701, Longyu 1708, Yaoyu 4123, Yaoyu 4126, Ruidan 26, Dingdan 6789, Zhengda 719, Longhuangbai 3, Jingdian 8, Yuanyu 093, Yunrui 119, Yunrui 668, and Yudan 8	60	It is 1600~2090 m above sea level and belongs to the subtropical mountain monsoon climate. The soil type is mainly red and red soil argillaceous rock. The soil pH value is 3.92~8.09, and the soil is generally acidic.	Mercury, arsenic, lead, copper, nickel, zinc, chromium, and cadmium; a total of 8 heavy metals in the regional agricultural land exceeded the standard, and the main pollutants were cadmium and lead.
3	Low-accumulation varieties screened in a project on soil pollution remediation and control of cultivated land in Zhehai Town, Huize County	Luodan 566, Xuanhui 7, Diwo 2, Xianyu 696, Xuanhuang Dan 5, and Huaxing 7	6	It is about 2050 m above sea level and belongs to the south temperate monsoon climate. The soil types are mainly red loam and red clay. The pH value of the soil ranges from 4.17 to 7.77, and the soil is generally acidic and slightly acidic.	There are Cd, Pb, Zn, Hg, As, Cu, and Ni pollutants in the cultivated soil of the project area. Cd is categorized as heavy pollution, Pb and Zn are mainly heavy pollution, and the rest are light and moderate pollution.
4	Low-accumulation varieties selected by "Lanping County Cultivated land Soil Pollution Control and Restoration Demonstration Project"	Xuanhuangdan 5, Quchen 11, Jingdian 4, Lushan No. 16, Chengxin 1, Chengxin 5, Longsheng 16, Qiangsheng 103, Yunrui 8, Huidan 4, Lushan 7, Xidan 8, Lushan 2, Lushan 6, and Qiushuoyu 6	15	It is about 2240 m above sea level and belongs to the subtropical, mountain main type of monsoon climate. The soil type is mainly purple soil, with a soil pH of 4.42~8.79, and the soil is generally acidic.	The soil Pb, Cd, Zn, and As in the project area severely exceed the standard; this is mainly due to the combined pollution of Cd and Pb.
5	Low-accumulation varieties selected in the pilot project of the Application of Soil Pollution Control and Remediation Technology for Agricultural Land in Haojia River Basin, Muding County	Luodan 299, Dayan 6, Enyu 8, Zhuoyu 299, Xianyu 696, Jinnong 109, Shengyu 6, Luodan 297, Jinqiuyu 35, Wugu 3861, Shengyu 8, Luodan 299, and Kenyu 1505	13	It is 1678~1880 m above sea level, which belongs to the subtropical monsoon climate area. The soil is mainly purple sandy mudstone soil, with a soil pH of 6.56~8.50, and the soil is generally alkaline.	The main pollution elements in the soil of the agricultural land in the project area are Cd and Cu.

2.1.3. Maize Variety Screening and Classification

The heavy metal pollution of the soil caused by mineral resource exploitation and the high geological composition of the soil have led to the use of arable land exceeding the safety standard, which has been a challenge for Yunnan province. Given that the state does not currently support the soil restoration of cultivated land, it is necessary to identify varieties with high biomass and low accumulation, high removal, feed suitability, and safety, focusing on maize in combination with agricultural planting methods, to ensure the safety of maize grains and improve the removal of heavy metals.

Maize varieties with high biomass and low accumulation of heavy metals have high biomass, medium or high heavy metal accumulation in all parts (roots, stems, and leaves), and low bioenrichment coefficient of grain, and the heavy metal contents of grain do not exceed the threshold of Pb 0.2 mg/kg, Cd 0.1 mg/kg [22].

Maize varieties with a high accumulation of heavy metals have a high extraction efficiency for heavy metals, and the heavy metals in the grain exceed the threshold value of Pb 0.2 mg/kg, Cd 0.1 mg/kg [22].

Feed-type maize varieties have high biomass, and the heavy metal contents in all parts (roots, stems, leaves, and grains) did not exceed the minimum threshold value of Pb 5 mg/kg, Cd 0.5 mg/kg [23].

Maize varieties with a low accumulation of heavy metals have a low extraction efficiency for heavy metals. The heavy metal contents of all parts (roots, stems, and leaves) do not exceed the minimum threshold value of Pb 5 mg/kg, Cd 0.5 mg/kg [23]. and the heavy metal contents of the grain do not exceed the threshold value of the of Pb 5 mg/kg, Cd 0.5 mg/kg [23].

2.2. Experimental Design

On 6 June 2022, a field trial was conducted on farmland within 5 km northeast of the enterprise. In the field experiment, 179 maize-variety screening areas were designed, and the planting density of maize was 35 cm × 35 cm. A total of 29 maize varieties were randomly planted in the field plot, and 3 types of maize grain were sown in each planting hole. For the application of base fertilizer, 7500 kg/hm^2 of organic fertilizer or 1500 kg/hm^2 of compound fertilizer was applied. For the topdressing application, the topdressing application consisted of urea 450 kg/hm^2 and compound fertilizer 300 kg/hm^2. The most effective practice is to apply maize topdressing twice: the first time at the jointing–booting stage (accounting for two-thirds of the total topdressing), and the second time by applying ear-grain fertilizer (accounting for one-third of the total topdressing).

2.3. Sample Collection and Determination

The mature maize was placed in the field for natural drying. The mature maize and its soil samples (0–20 cm) were collected on 30 September 2022, and the five-point sampling method was adopted in each plot to collect the maize and soil samples. The maize plant samples were divided into four parts: root, stem, leaf, and maize, and washed with tap water, Na_2-EDTA, and deionized water, in turn. The cleaned plant material was baked in the oven at 105 °C for 30 min and then at 75 °C for 48 h. After drying, we recorded the dry weight of each part, which was ground with a stainless-steel grinder and then sieved with a 100-mesh screen. The soil samples were naturally air-dried in a greenhouse, and the roots and stones of the plants in the soil samples were removed and screened through a 100-mesh sieve. After screening the soil and maize, the heavy metal contents of the soil and maize were stored in sealed plastic pockets until analysis.

The methods for the analysis and determination of the maize and soil were that the soil samples were digested with aqua regia and $HClO_4$, and the plant samples were digested with HNO_3-H_2O_2. The recovery of Cd and Pb in samples was conducted using inductively coupled plasma mass spectrometry (ICP-MS), with a result of 93–98%, which meets the quality-control requirements of heavy metal detection.

2.4. Statistical Analysis of Data

WPS Excel 2023 was used to process the experimental data, SPSS 19.0 was used for the analysis of variance (ANOVA), and Tukey's HSD (honestly significant difference) method was used for multiple comparisons of the mean values. SPSS 19.0 was used for cluster analysis, and Origin 2022 software was used for mapping.

(1) In order to compare the accumulation and transfer ability of Pb and Cd among the 29 maize varieties, the biological enrichment coefficient (BCF) and transfer coefficient (TF) of the maize varieties in different parts were calculated as follows.

BCF = heavy metal content in maize parts/heavy metal content in the soil;

TF (stem and leaf) = (stem biomass × stem heavy metal content + leaf biomass × leaf heavy metal content)/(root biomass × root heavy metal content) [20];

TF (grain) = (grain biomass × grain heavy metal content)/(stem biomass × stem heavy metal content + leaf biomass × leaf heavy metal content) [20];

(2) In order to compare the accumulation and extraction of Pb and Cd in the 29 maize varieties, the extraction efficiency and accumulation of heavy metals in maize were calculated as follows.

Heavy metal extraction efficiency = heavy metal accumulation of each plant (root biomass × root heavy metal content + stem biomass × stem heavy metal content + leaf biomass × leaf heavy metal content + grain biomass × grain heavy metal content) × planting density (30 × 30 cm, 15 plants)/total heavy metal content in soil (soil bulk weight 1.3 g/cm^3 × soil volume (1 m^2 × 0.2 m) × soil heavy metal content (mg/kg)) ×100% [20];

Heavy metal accumulation = heavy metal content of each part of the maize × biomass of each part.

3. Results

3.1. Effects of Pb and Cd in Soil on the Growth of Maize Varieties

The plant height, biomass, and yield of maize under Pb and Cd stress are usually inhibited to some extent; therefore, the plant height, biomass, and 100-grain weight are used as tolerance indexes of maize under Pb and Cd stress. Yayu 719 had the highest plant height, and Longdan 1604 had the lowest plant height. The 100-grain weight of Longhuangbai 3 was the heaviest, and the 100-grain weight of Longbai 1 was the lowest. The average yield per hectare of Qiuqing 88 was the highest, and the average yield per hectare of Huidan 936 was the lowest. The dry weight of Qiuqing 88 (roots, stems, leaves, and grains) was the highest, and that of Qinrui 47 (roots, stems, leaves, and grains) was the lowest (Table 3).

It can be seen from Table 3 above that under Pb and Cd stress, there were significant differences in plant height, 100-grain weight, yield, and biomass of each maize part (roots, stems, leaves, and grains) of the 29 maize varieties ($p < 0.05$), indicating that they adapt differently to soil polluted with Pb and Cd. The plant height of the 29 maize varieties ranged from 193 to 281 cm, with an average height of 239 cm. Longdan 1604 and Longrui 3869 were the most affected by heavy metals, and the plant height was lower than 200 cm. Longyu 1708 and Yayu 719 were the least affected by heavy metals, and their plant height was 281 cm. The 100-grain weight ranged from 28.3 to 48.4 g, with an average of 36.3 g. Longbai 1 was the most affected by heavy metals, and its 100-grain weight was the least. Longhuangbai 3 was the least affected by heavy metals and had the largest 100-grain weight, with biomass values between 133.7 and 317.9 g. Jingdian 8 was the most affected by heavy metals, and its biomass was the least, followed by Hongdan 6. Qiuqing 88 was the least affected by heavy metals and had the largest biomass, followed by Longhuangbai 3.

The growth of Longhuangbai 3, Jinqiuyu 35, Jinyi 418, and Qiuqing 88 is less affected by heavy metals; thus, these varieties can be used as heavy metal-resistant maize. Under heavy metal stress, different maize varieties have different tolerance levels to heavy metals, which may be related to the detoxification mechanism and genes of maize. Under the combined stress of Cd-Zn, the plant height, leaf area, biomass, and yield of maize, as well as the contents of Cd and Zn in maize roots, stems, leaves, and grains, showed significant differences among varieties.

Table 3. Biomass values of different maize varieties in heavy metal-contaminated soil around a typical lead mine.

Number	Maize Variety	Plant Height (cm)	100-Grain Weight (g)	Production per 0.067 Hectare (kg)	Weight of Different Parts of Maize (g/plant)			
					Root	Stem	Leaf	Grain
1	Fengdeng 2025	254 ± 10.0 cdefg	40.0 ± 1.5 cde	550 ± 38.3 cde	18.2 ± 0.9 efg	31.9 ± 0.5 def	27.4 ± 2.7 ef	85.9 ± 6.6 lmn
2	Hongdan 6	236 ± 15.5 efghij	40.7 ± 0.5 cd	527 ± 25.3 cdef	17.7 ± 1.1 fgh	25.3 ± 0.7 ghij	21.0 ± 2.4 ghij	75.2 ± 6.2 no
3	Huidan 936	255 ± 11.7 cdef	30.5 ± 0.9 mn	323 ± 11.1 l	14.0 ± 0.1 mn	19.8 ± 0.8 lmn	19.3 ± 0.8 jklm	123.6 ± 3.7 ef
4	Jinqiuyu 35	263 ± 4.5 abcd	31.5 ± 1.4 klm	349 ± 17.4 kl	15.4 ± 0.2 k	57.1 ± 7.9 a	51.1 ± 3.3 a	131.4 ± 1.2 de
5	Jinqiuyu 755	221 ± 9.5 ijkl	35.8 ± 1.2 ghij	565 ± 22.6 cd	19.4 ± 0.8 d	26.3 ± 2.2 ghij	24.8 ± 2.1 efg	99.8 ± 10.0 hij
6	Jinyi 418	263 ± 4.9 abcd	38.2 ± 2.4 defg	536 ± 27.3 cde	17.2 ± 0.6 hi	46.4 ± 3.7 b	33.9 ± 0.9 d	131.3 ± 2.2 de
7	Jinyu 108	249 ± 16.0 defgh	42.6 ± 1.2 bc	640 ± 17.2 b	18.8 ± 0.7 de	25.1 ± 1.0 ghijk	21.1 ± 2.7 ghij	98.4 ± 4.4 hijk
8	Jingdian 8	257 ± 11.7 bcde	37.6 ± 2.2 efg	493 ± 8.4 efgh	16.3 ± 0.1 ijk	25.8 ± 0.6 ghij	20.3 ± 1.4 hijkl	71.4 ± 2.3 o
9	Kangyu 8	249 ± 5.6 defgh	36.5 ± 0.4 fghi	659 ± 5.0 b	21.8 ± 0.7 b	22.7 ± 0.2 jkl	19.8 ± 0.2 ijkl	126.4 ± 5.1 e
10	Kenyu 1505	225 ± 27.0 hijk	30.6 ± 0.4 mn	380 ± 11.3 jkl	14.4 ± 0.1 lm	29.9 ± 1.6 efg	25.1 ± 3.3 ef	137.6 ± 2.6 d
11	Kongyu 829	235 ± 3.5 efghij	36.9 ± 1.1 fghi	559 ± 33.2 cd	17.1 ± 0.7 hi	25.8 ± 0.5 ghij	23.5 ± 0.6 fghi	75.7 ± 6.3 mno
12	Longbai 1	215 ± 10.6 jklm	28.3 ± 1.0 n	355 ± 14.0 kl	14.3 ± 0.2 m	16.4 ± 1.7 n	13.7 ± 0.4 n	74.7 ± 3.1 o
13	Longdan 1604	193 ± 7.8 m	39.3 ± 2.3 def	567 ± 21.7 cd	20.6 ± 0.3 c	17.4 ± 1.0 mn	15.6 ± 1.8 mn	102.7 ± 10.4 hi
14	Longdan 1701	230 ± 7.2 ghij	39.3 ± 3.4 def	549 ± 27.0 cde	17.5 ± 0.1 gh	23.7 ± 0.3 ijkl	18.4 ± 1.0 jklm	107.0 ± 2.5 gh
15	Longhuanbai 3	260 ± 15.3 abcd	48.4 ± 1.5 a	783 ± 6.4 a	21.2 ± 0.6 bc	40.3 ± 1.5 c	35.5 ± 2.4 d	164.4 ± 4.1 bc
16	Longrui 3869	197 ± 6.6 lm	37.1 ± 1.4 efgh	463 ± 15.9 ghi	15.4 ± 0.3 kl	22.2 ± 2.1 jklm	19.2 ± 1.1 jklm	88.4 ± 1.5 kl
17	Longyu1 708	281 ± 12.1 ab	38.4 ± 1.2 defg	647 ± 48.6 b	19.4 ± 0.05 d	29.6 ± 0.8 efgh	18.1 ± 1.9 jklm	113.8 ± 5.5 fg
18	Ludan 12	236 ± 9.0 efghij	37.7 ± 1.3 defg	410 ± 70.2 ijk	13.1 ± 0.5 n	20.3 ± 0.4 klmn	17.0 ± 0.95 klmn	124.7 ± 2.8 e
19	Qinrui 3817	244 ± 12.7 defghi	36.5 ± 2.5 fghi	521 ± 43.9 cdefg	18.2 ± 0.1 efg	22.6 ± 0.9 jkl	16.0 ± 1.7 lmn	173.2 ± 7.0 b
20	Qinrui 47	205 ± 8.0 klm	33.9 ± 1.5 ijkl	471 ± 25.8 fghi	15.5 ± 0.3 k	23.8 ± 0.2 ijkl	18.0 ± 1.0 jklm	69.0 ± 0.9 o
21	Qiuqing 88	216 ± 11.1 jklm	43.8 ± 0.6 b	773 ± 13.5 a	18.3 ± 0.1 efg	61.0 ± 1.9 a	43.6 ± 2.2 b	195.0 ± 7.9 a
22	Shangdan 2012	274 ± 6.8 abc	36.9 ± 0.6 fghi	539 ± 17.4 cde	19.3 ± 0.2 d	28.2 ± 0.3 fghi	20.6 ± 1.0 hijk	90.2 ± 2.9 jkl
23	Shangyu 3899	247 ± 4.5 defgh	34.4 ± 1.9 hijk	493 ± 42.8 efgh	18.2 ± 0.1 efg	23.4 ± 1.4 ijkl	19.7 ± 0.8 ijkl	86.0 ± 8.1 lm
24	Tianyan 29	222 ± 14.0 ijk	33.2 ± 1.1 jklm	506 ± 43.0 defg	16.5 ± 0.3 ij	33.8 ± 2.7 de	26.8 ± 2.1 ef	163.5 ± 1.2 bc
25	Tianyan 31	254 ± 11.9 cdef	30.2 ± 0.2 mn	436 ± 24.9 hij	15.7 ± 0.4 jk	36.2 ± 3.2 cd	27.4 ± 2.9 ef	159.6 ± 4.7 c
26	Wugu 1790	240 ± 8.50 defghi	32.3 ± 1.2 klm	463 ± 9.7 ghi	15.8 ± 0.2 jk	26.5 ± 2.4 ghij	23.8 ± 1.9 fgh	158.8 ± 2.9 c
27	Wugu 3861	231 ± 8.5 fghij	31.2 ± 1.0 lmn	363 ± 16.9 kl	13.8 ± 0.6 mn	24.7 ± 2.1 hijk	19.7 ± 1.2 ijkl	132.4 ± 5.7 de
28	Xinzhongyu 801	201 ± 18.8 klm	36.1 ± 0.4 ghij	576 ± 16.9 c	18.6 ± 0.1 def	31.6 ± 4.6 def	28.6 ± 2.7 e	100.8 ± 4.7 hij
29	Yayu 719	281 ± 15.7 a	33.9 ± 1.2 ijkl	563 ± 56.3 cd	27.4 ± 0.3 a	47.3 ± 2.8 b	39.6 ± 1.2 c	92.1 ± 5.5 ijkl

Different letters in each column indicate that the same index has significant differences among different maize varieties ($p < 0.05$).

3.2. Pb and Cd Contents in Different Plant Parts of Maize

The Pb content in the roots of the 29 maize varieties ranged from 2.13 to 19.46 mg/kg. Jinqiuyu 35 was the lowest, and Wugu 1790 was the highest. The Pb content in the roots of 15 maize varieties, including Wugu 1790, Wugu 3861, Longbai 1, Xinzhongyu 801, Hongdan 6, Longdan 1604, Kangyu 8, Jinyi 418, Qinrui 3817, Qinrui 47, Huidan 936, Kongyu 829, Jingdian 8, Fengdeng 2025, and Longyu 1708, exceeded the Feed Health Standard (GB 13078-2017, minimum Pb limit $\leq$ 5 mg/kg) threshold. The Cd content in the roots ranged from 2.13 to 19.46 mg/kg. The Jinqiuyu 755 and Ludan 12 varieties had the lowest Cd content, and the Jinqiuyu 35 had the highest Cd content. Among them, only four maize varieties—Fengdeng 2025, Jinqiuyu 755, Kangyu 8, and Ludan 12—had a Cd content lower than the threshold value of the Feed Health Standard (GB 13078-2017, with a minimum limit of Cd $\leq$ 0.5 mg/kg) (Figure 1a).

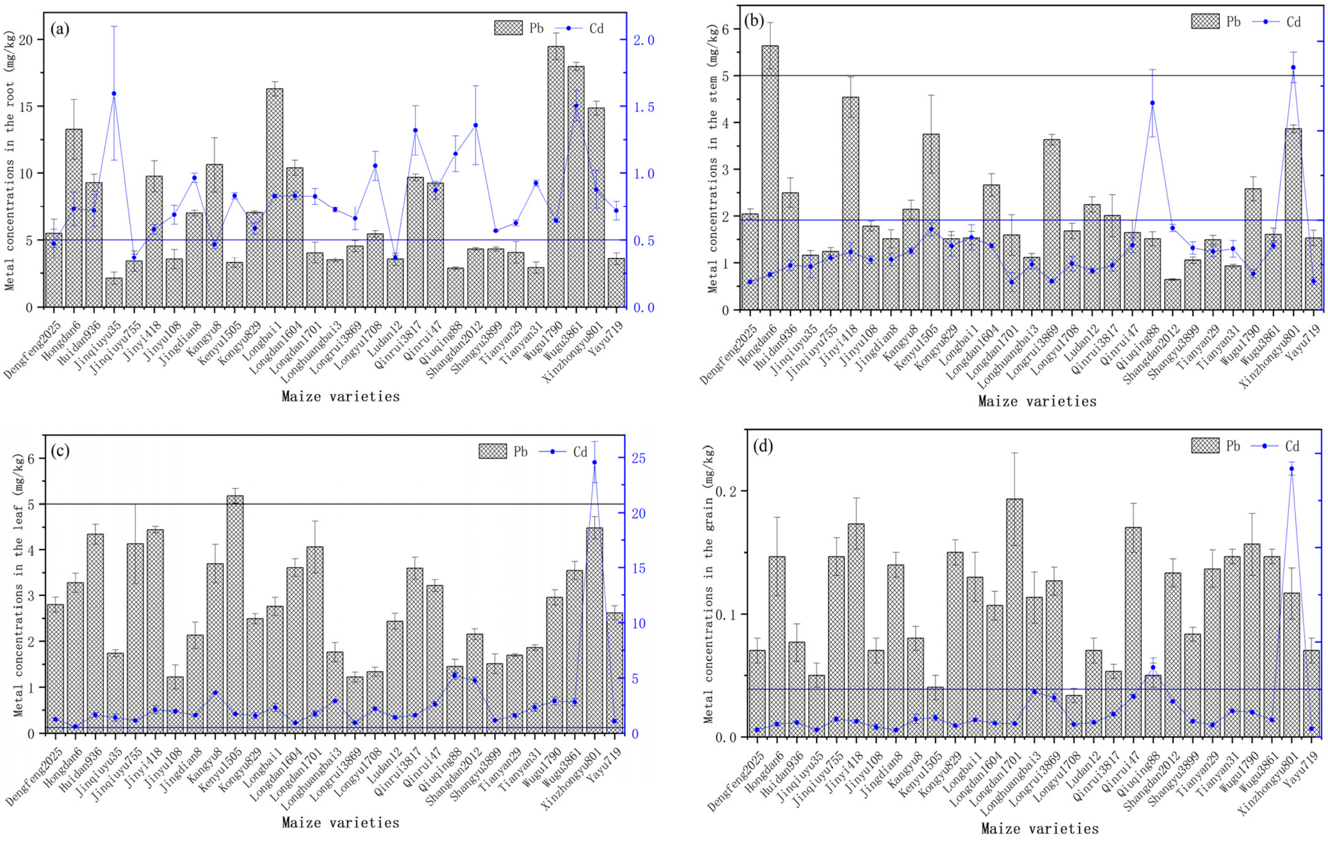

Figure 1. Contents of Pb and Cd in roots (**a**), stems (**b**), leaves (**c**), and grains (**d**) of the 29 maize varieties.

The Pb content in the stems of the 29 maize varieties ranged from 0.64 to 5.64 mg/kg, with the lowest Pb content in the stems of Shangdan 2012 and the highest in Hongdan 6. Only the Pb content in stems of the Hongdan 6 maize variety exceeded the threshold of Pb 5 mg/kg [23]; the other 28 maize varieties did not exceed it. The stem Cd content ranged from 0.15 to 1.35 mg/kg, the stem Cd content of Longdan 1701 was the lowest, and that of Xinzhongyu 801 was the highest. Only two maize varieties, Xinzhongyu 801 and Qiuqing 88, had Cd contents in their stems exceeding the threshold of Cd 0.5 mg/kg [23]; the other 27 varieties did not exceed the threshold (Figure 1b).

The Pb content in the leaves of the 29 maize varieties ranged from 1.22 to 5.17 mg/kg, with the lowest content in the leaves of Longrui 3869 and Jinyu 108 and the highest in Kenyu 1505. The Pb content in leaves of the Kenyu 1505 maize variety exceeded the threshold of Pb 5 mg/kg [23], and the other 28 maize varieties did not exceed the threshold. The Cd content in leaves ranged from 0.61 to 24.5 mg/kg, with the lowest in Hongdan 6 and the highest in Xinzhongyu 801. Among them, the Cd content of Xinzhongyu 801 leaves was much higher than that of the other varieties. At the same time, the content of Cd in the leaves of the 29 maize varieties exceeded the threshold of Cd 0.5 mg/kg, and the leaves of maize had strong enrichment capacity for Cd (Figure 1c).

The content of Pb in grain of 29 maize varieties ranged from 0.01 mg/kg to 0.57 mg/kg. Longyu 1708 grain had the lowest lead content, while longdan 1701 grain had the highest lead content. All maize varieties met the standard limit of lead content [22,23]. The content of Cd in the grain ranged from 0.61 to 24.5 mg/kg. Jingdian 8 had the lowest content, and Xinzhongyu 801 had the highest content. The Cd content of Xinzhongyu 801 was much higher than that of other varieties. The content of Cd in the grain of the Qiuqing 88 and Xinzhongyu 801 varieties exceeded the threshold of the Limit Cd 0.1 mg/kg [22], and the content of Cd in the grain of Xinzhongyu 801 varieties exceeded the minimum limit Cd 0.5 mg/kg [23] (Figure 1d).

The absorption capacity of heavy metals in different organs of the same maize is also different. The results showed that there were significant differences in Pb and Cd contents in roots, stems, leaves, and grains of the 29 maize varieties under heavy metal stress ($p < 0.05$), satisfying the order of leaf > stem > root > grain. Heavy metals mainly accumulate in the roots, stems, and leaves of maize, and the content of metals in the grain is generally low. Therefore, by planting maize and recycling its roots, straw, and other residues, the purpose of soil restoration can be gradually achieved. The Cd content of Xinzhongyu 801 was much higher than that of other varieties. The content of Cd in the grain of the Qiuqing 88 and Xinzhongyu 801 varieties exceeded the threshold value of Cd 0.1 mg/kg [22]. These results indicate that different maize varieties have a wide range of genetic variation, while the same maize varieties have tissue specificity. Before entering the grain, heavy metals are first trapped by the vegetative organs, then shunted by the nonedible parts of the reproductive organs, and finally arrive in the grain [24]. Previous studies have shown that the accumulation of different heavy metals in the different plant parts of maize is different. In the future, it is necessary to further study the accumulation of different heavy metals in the different plant parts of maize, which will play an important role in the rational utilization of different parts of maize after harvest.

Different letters indicate that there were significant differences in the contents of the same heavy metals in the plant parts of the 29 maize varieties ($p < 0.05$).

3.3. Biological Enrichment and Transport of Pb and Cd in Maize Varieties

3.3.1. Biological Enrichment of Pb and Cd in Maize Varieties

The BCF of the 29 maize varieties ranged from 0.036 to 0.179, with an average value of 0.089. The lowest BCF of Pb was for Jinqiuyu 35, and the highest BCF was for Wugu 1790 (Figure 2a). The BCF of Cd in the 29 maize varieties ranged from 1.06 to 18.6, with an average value of 2.76. The lowest BCF of Cd was for Hongdan 6, and the highest BCF was for Xinzhongyu 801 (Figure 2b).

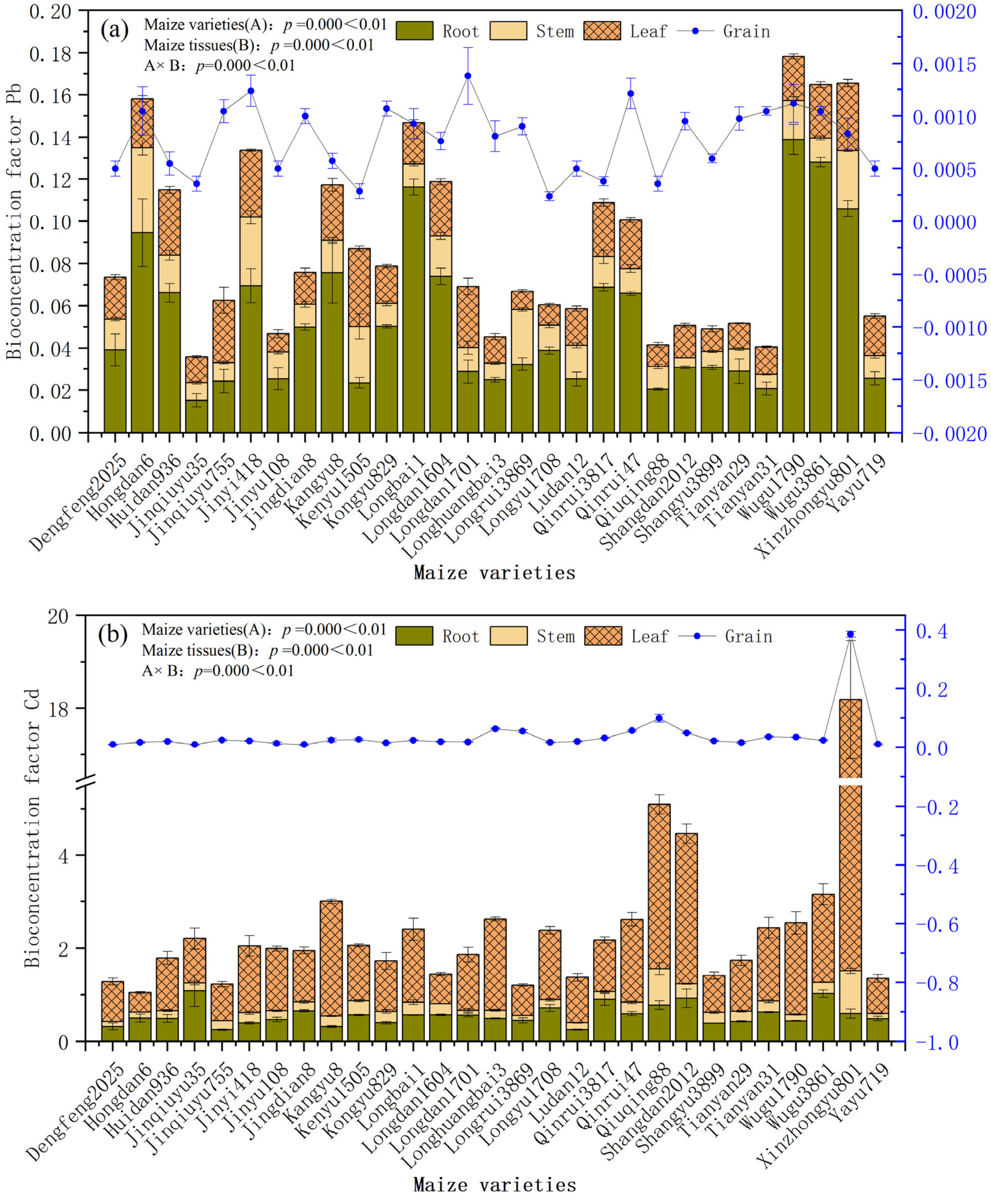

Figure 2. Biological enrichment coefficients of lead and cadmium in different plant parts of different maize varieties.

3.3.2. Transport of Pb and Cd in Maize Varieties

The TF of Pb in the 29 maize varieties ranged from 0.271 to 2.77, with an average value of 0.886 (Figure 3). The lowest TF of Pb was for Longbai 1, and the highest TF was for Kanyu 1505. The TF of Cd in the 29 maize varieties ranged from 1.16 to 31.0, with an average value of 4.15. The lowest TF of Cd was for Jinqiuyu 35, and the highest was for Xinzhongyu 801. The TF of Cd in the Xinzhongyu 801 variety was much higher than that of the other varieties. The stem and leaf TF of Pb ranged from 0.271 to 2.77, with an average value of 0.886. The lowest TF of Pb was for Longbai 1, and the highest TF of Pb was for Kenyu 1505. The stem and leaf TF of Cd in the 29 maize varieties ranged from

1.16 to 31.0, with an average value of 4.15. The lowest stem and leaf TF of Cd was for Jinqiuyu 35, and the highest was for Xinzhongyu 801. The stem and leaf TF of Cd in the Xinzhongyu 801 variety was much higher than that of the other varieties. The grain TF of Pb ranged from 0.005 to 0.053, with an average value of 0.025. The lowest grain TF of Pb was for Kenyu 1505 and the highest was for Tianyan 31. The grain TF of Cd in the 29 maize varieties ranged from 0.05 to 0.053, with an average value of 0.025. The lowest grain TF of Cd was for Kenyu 1505 and the highest was for Tianyan 31.

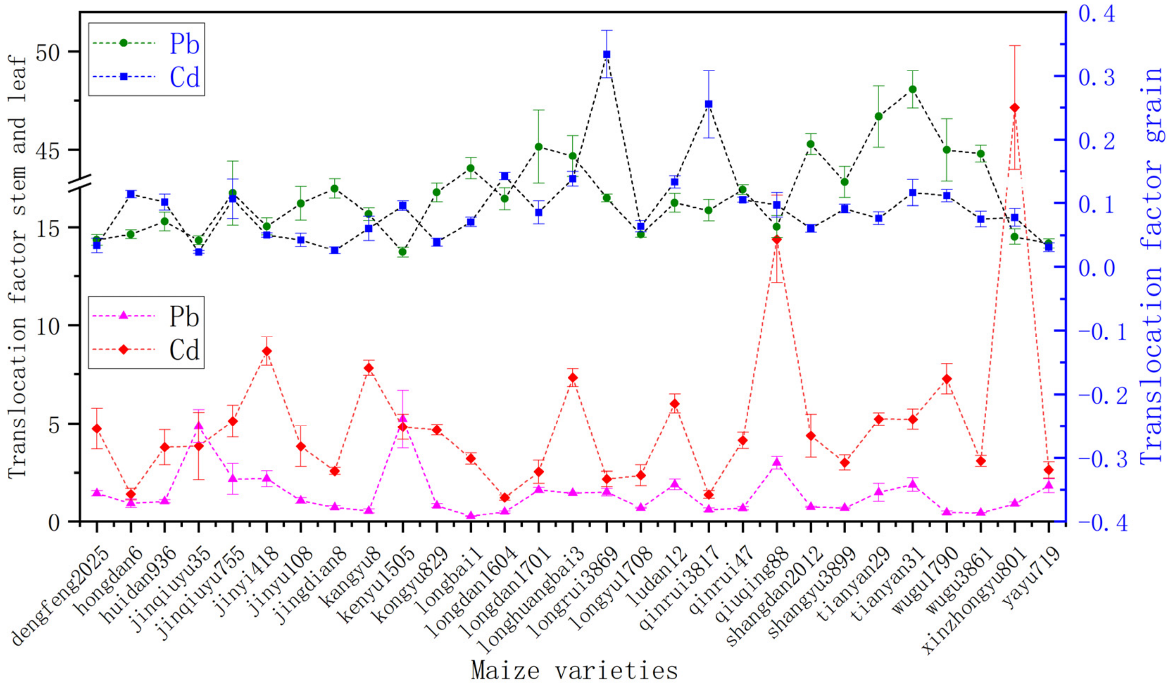

Figure 3. Transport coefficients of cadmium and lead in different plant parts of different maize varieties.

The results of two-factor ANOVA showed that the bioenrichment coefficients of Pb and Cd were significantly affected by maize varieties, maize plant parts, and their interactions ($p < 0.01$). The BCF, TF, stem and leaf TF, and grain TF of Cd were stronger than those of Pb.

In the 29 maize varieties, the Pb BCF was less than one, indicating that the Pb enrichment ability from the soil to the roots, stems, leaves, and grains was weak. However, for nine varieties, including Kenyu 1505, Jinqiuyu 755, Longdan 1701, Jinqiuyu 35, Ludan 12, Yanyu 719, Longrui 3869, Qiuqing 88, and Tianyan 31, the PbTF values were greater than one, indicating that Pb had a strong ability to transport from roots to stems, leaves, and grains. At the same time, both the stem and leaf TF and grain TF were much less than one, indicating that the transport capacity of Pb from stem and leaf to grain was weak.

CdTF was greater than one in all 29 maize varieties, indicating that Cd had a strong ability to transport from the root to the stem, leaf, and grain. The CdTF of Zhenrui 3817 was the lowest, and the CDTF of Xinzhongyu 801 was the highest—much higher than those of the other varieties. The lowest CdTF capacity was for Kenyu 1505, and the highest was for Tianyan 31. The CdTF capacity of stems and leaves was the lowest in Hongdan 6 and the highest in Xinzhongyu 801.

The contents of Pb and Cd, and BCF and TF, in the roots, stems, and leaves of the 29 tested maize varieties were significantly different ($p < 0.05$). There are significant differences in the accumulation and enrichment of heavy metals in crops, and there are significant differences in the accumulation of cadmium in the grain of different maize varieties. Moreover, there are also significant differences in the accumulation capacity of cadmium in different maize varieties. Different maize varieties have a variety of mechanisms for the absorption and transport of Pb and Cd, resulting in great differences in metal content and metal distribution among maize varieties. On the one hand, the mechanism of heavy metal tolerance in low-accumulation plants is usually related to the defense function of the antioxidant system [25]. Different crops have different absorption and accumulation capacities for cadmium, and the same is true for different varieties of a single crop [26]. In this work, the BCF of Pb and Cd in 29 maize varieties showed that the bioenrichment capacity of Pb and Cd in the leaves was higher than that in the stem and grain; therefore, the leaf was the main accumulator of heavy metals among the organs. On the other hand, the TF values of Pb and Cd in the 29 maize varieties were 0.005–0.053 and 0.05–0.053, respectively, indicating that the transport capacity of Pb and Cd from the stem and leaf to the grain was very weak. Therefore, if the grain TF is low, the transfer of heavy metals from stems and leaves to edible parts is low, and the proportion of heavy metals entering the food chain is correspondingly reduced, thus ensuring the safety of agricultural products.

3.4. Extraction Efficiency of Pb and Cd in Maize Varieties and Accumulation of Different Parts

The three major grains in Yunnan province are rice, maize, and wheat, among which the biomass of maize is higher than that of the other two grains, and the planting area of maize is large in the province. The roots, stems, leaves, and grains of maize can accumulate heavy metals during the growth process. While ensuring the yield of maize, taking maize as a restoration material to extract heavy metals from soil is the direction of heavy metal restoration in cultivated soil in the future. The extraction efficiency of Pb and Cd and the accumulation amount of Pb and Cd in different parts (roots, stems, leaves, and grains) of the 29 maize varieties were significantly different ($p < 0.05$). The extraction efficiency of Pb was 0.00577~0.0227% among the 29 maize varieties. The lowest extraction efficiency of Pb was for Shangyu 3899, and the highest extraction efficiency was for Jin Billion 418. The extraction efficiency of Cd ranged from 0.00577 to 0.0227%. The maize variety with the lowest extraction efficiency of Pb was Hongdan 6, and that with the highest extraction efficiency was Xinzhongyu 801 (Table 4).

The accumulation abilities of heavy metals in different parts of the same maize variety were different. There were significant differences in Pb and Cd accumulation in roots, stems, leaves, and grains of the 29 maize varieties under heavy metal stress ($p < 0.05$). According to the accumulation of heavy metal Pb, the general maize varieties were in the order of root > leaf > stem > grain. According to the accumulation of heavy metal Cd, the order of leaves > root > stem > grain was generally satisfied.

Table 4. Extraction Efficiency of Pb and Cd in Maize Varieties and Accumulation of Pb and Cd in different Parts.

Number	**Maize Variety**	**Pb Accumulation (ug)**				**Cd Accumulation (ug)**				**Pb Extraction Efficiency (%)**	**Cd Extraction Efficiency (%)**
		Root	**Stem**	**Leaf**	**Grain**	**Root**	**Stem**	**Leaf**	**Grain**		
1	Fengdeng 2025	99.6 ± 17.1 hijk	65.2 ± 3.7 fghi	76.8 ± 10.6 def	6.04 ± 1.2 jkl	8.6 ± 2.3 jkl	4.95 ± 0.3 hij	34.6 ± 5.9 efghi	1.30 ± 0.3 l	0.0102 ± 0.001 hijk	0.194 ± 0.03 ghi
2	Hongdan 6	236 ± 54.4 cd	143 ± 8.7 b	68.9 ± 11.7 efgh	10.9 ± 1.9 fgh	12.9 ± 1.8 ghij	4.94 ± 0.3 hij	12.8 ± 2.1 i	2.02 ± 0.1 ijkl	0.0189 ± 0.002 b	0.128 ± 0.009 i
3	Huidan 936	130 ± 9.8 gh	49.4 ± 5.7 ghij	83.7 ± 5.7 de	9.44 ± 1.6 ghijk	10.1 ± 1.7 ijk	4.88 ± 0.5 hij	32.2 ± 3.7 efghi	3.75 ± 0.3 ghijk	0.0112 ± 0.0008 fghi	0.200 ± 0.008 fghi
4	Jinqiuyu 35	32.8 ± 7.0 p	66.8 ± 12.1 fghi	88.9 ± 8.8 cd	6.56 ± 1.3 ijkl	24.6 ± 8.1 ab	13.8 ± 4.2 cd	71.8 ± 13.1 cdef	1.97 ± 0.3 ijkl	0.00802 ± 0.0006 lmno	0.439 ± 0.04 cd
5	Jinqiuyu 755	66.2 ± 16.6 lmno	32.7 ± 2.1 jkl	104 ± 30.3 c	14.7 ± 2.9 ef	7.1 ± 0.7 kl	7.59 ± 0.8 defghij	28.4 ± 2.1 efghi	3.78 ± 0.8 ghijk	0.00893 ± 0.00130 jklm	0.184 ± 0.005 hi
6	Jinyi 418	168 ± 18.1 ef	211 ± 34.6 a	150 ± 4.8 a	22.8 ± 2.9 abc	10.0 ± 0.9 ijk	15.0 ± 2.6 c	71.8 ± 12.8 cde	4.34 ± 0.5 gh	0.0227 ± 0.001 a	0.396 ± 0.06 cde
7	Jinyu 108	66.7 ± 13.2 lmno	44.8 ± 4.1 ijk	26.3 ± 8.3 mn	6.87 ± 0.8 ijkl	13.0 ± 1.6 ghij	6.99 ± 0.8 efghij	41.7 ± 6.7 efghi	2.06 ± 0.5 ijkl	0.00595 ± 0.0009 pq	0.250 ± 0.03 efghi
8	Jingdian 8	114 ± 2.9 ghi	39.1 ± 6.0 jkl	43.2 ± 6.8 jklmn	10.0 ± 0.9 ghi	15.7 ± 0.5 efgh	7.24 ± 1.0 efghij	33.0 ± 1.0 efghi	1.04 ± 0.2 l	0.00848 ± 0.0006 klm	0.223 ± 0.008 efghi
9	Kangyu 8	230 ± 37.6 cd	48.5 ± 4.4 hij	73.1 ± 8.4 defg	10.1 ± 0.8 ghi	10.1 ± 0.5 ijk	7.44 ± 0.3 defghij	71.8 ± 0.7 cdef	4.79 ± 1.4 fgh	0.0149 ± 0.001 cd	0.369 ± 0.003 def
10	Kenyu 1505	47.3 ± 4.9 nop	113 ± 29.3 cd	130 ± 18.7 b	5.50 ± 1.4 kl	12.0 ± 0.3 hij	13.4 ± 0.8 cde	44.3 ± 6.7 efghi	5.54 ± 0.7 efg	0.0122 ± 0.002 efg	0.295 ± 0.03 defghi
11	Kongyu 829	120 ± 6.4 gh	39.1 ± 4.0 jkl	58.7 ± 3.7 fghijk	11.4 ± 1.6 fg	10.0 ± 0.9 ijk	9.23 ± 1.5 cdefghij	37.7 ± 6.7 efghi	1.81 ± 0.04 jkl	0.00944 ± 0.0002 ijkl	0.230 ± 0.03 efghi
12	Longbai 1	234 ± 4.7 cd	25.0 ± 2.6 kl	37.6 ± 1.6 lmn	9.68 ± 1.1 ghij	11.9 ± 0.3 hij	6.63 ± 1.5 fghij	31.6 ± 5.1 efghi	2.70 ± 0.3 hijkl	0.0126 ± 0.0001 ef	0.207 ± 0.02 fghi
13	Longdan 1604	214 ± 9.5 d	46.2 ± 1.7 hijk	56.7 ± 9.3 ghijkl	10.9 ± 1.1 fgh	17.1 ± 0.4 defg	6.24 ± 0.6 ghij	14.7 ± 2.1 i	2.99 ± 0.5 hijkl	0.0135 ± 0.00008 de	0.161 ± 0.01 i
14	Longdan 1701	70.5 ± 13.4 klmno	37.8 ± 10.6 jkl	75.1 ± 14.6 defg	20.7 ± 3.8 bcd	14.4 ± 1.0 ghi	3.63 ± 1.2 j	32.6 ± 5.6 efghi	3.03 ± 0.2 hijkl	0.00840 ± 0.001 ghij	0.210 ± 0.02 fghi
15	Longhuangbai 3	73.7 ± 2.7 jklmno	45.0 ± 2.1 ijk	62.3 ± 4.1 fghij	18.7 ± 3.6 de	15.4 ± 0.6 fgh	10.1 ± 0.6 cdefghi	102 ± 4.9 c	15.5 ± 0.6 c	0.00821 ± 0.0004 lmn	0.562 ± 0.02 c
16	Longrui 3869	69.6 ± 5.5 klmno	80.6 ± 10.1 ef	23.6 ± 3.3 n	11.2 ± 1.2 fg	10.2 ± 1.4 ijk	3.50 ± 0.3 j	18.2 ± 1.1 i	7.24 ± 0.6 de	0.00761 ± 0.0007 lmnop	0.153 ± 0.008 i
17	Longyu 1708	105 ± 4.8 hij	49.6 ± 4.0 ghij	24.2 ± 1.1 n	3.77 ± 0.4 l	20.4 ± 2.1 bcde	7.61 ± 1.4 defghij	39.9 ± 6.1 efghi	2.99 ± 0.1 hijkl	0.00753 ± 0.0003 mnopq	0.278 ± 0.03 defghi
18	Ludan 12	46.3 ± 7.4 nop	45.6 ± 2.5 hijk	41.4 ± 1.4 klmn	8.75 ± 1.4 ghijk	4.80 ± 0.3 l	4.40 ± 0.2 ij	24.4 ± 1.0 ghi	3.83 ± 0.3 ghij	0.00584 ± 0.0004 pq	0.147 ± 0.006 i
19	Qinrui 3817	176 ± 4.5 e	45.6 ± 11.7 hijk	60.1 ± 9.9 fghijk	9.21 ± 0.6 ghijk	24.0 ± 3.3 abc	5.59 ± 0.6 hij	27.3 ± 4.1 fghi	8.27 ± 0.8 d	0.0120 ± 0.0009 efgh	0.256 ± 0.02 efghi
20	Qinrui 47	143 ± 3.1 fg	39.2 ± 6.2 jkl	57.8 ± 5.2 fghijk	11.7 ± 1.3 fg	13.5 ± 1.3 ghi	8.57 ± 1.0 cdefghij	47.1 ± 3.4 efghi	5.84 ± 0.2 efg	0.0103 ± 0.0005 ghij	0.294 ± 0.02 defghi
21	Qiuqing 88	52.3 ± 1.2 mnop	92.5 ± 11.9 de	63.6 ± 8.6 fghi	9.74 ± 1.8 ghij	20.9 ± 2.4 bcd	70.6 ± 13.5 a	227 ± 20.7 b	28.6 ± 3.5 b	0.00897 ± 0.0008 jklm	1.360 ± 0.09 b
22	Shangdan 2012	83.5 ± 1.0 ijklm	18.1 ± 0.6 l	44.3 ± 3.5 ijklm	12.0 ± 0.8 fg	26.2 ± 5.6 a	12.9 ± 0.7 cdef	97.9 ± 8.9 cd	6.68 ± 0.3 def	0.00650 ± 0.0001 nopq	0.563 ± 0.03 c
23	Shangyu 3899	78.6 ± 2.2 jklmn	24.7 ± 1.4 kl	29.7 ± 3.0 mn	7.19 ± 1.1 hijkl	10.4 ± 0.1 ijk	8.09 ± 1.2 defghij	23.0 ± 3.2 hi	2.85 ± 0.5 hijkl	0.00577 ± 0.0001 q	0.174 ± 0.02 i
24	Tianyan 29	66.9 ± 13.9 lmno	50.6 ± 6.4 ghij	45.4 ± 3.5 ijklm	22.3 ± 2.4 abcd	10.3 ± 0.3 ijk	11.0 ± 1.0 cdefgh	42.9 ± 2.8 efghi	4.14 ± 0.7 ghi	0.00762 ± 0.0003 lmnop	0.268 ± 0.02 defghi
25	Tianyan 31	45.7 ± 7.8 op	33.6 ± 1.8 jkl	50.8 ± 3.8 hijkl	23.4 ± 1.6 ab	14.5 ± 0.7 ghi	12.4 ± 2.3 cdefg	63.2 ± 6.6 cdefgh	8.67 ± 0.5 d	0.00632 ± 0.0002 opq	0.387 ± 0.03 de
26	Wugu 1790	308 ± 16.0 a	68.6 ± 11.6 fgh	70.2 ± 6.8 defgh	24.9 ± 4.0 a	10.2 ± 0.3 ijk	5.29 ± 0.8 hij	68.6 ± 6.2 cdefg	8.20 ± 0.2 d	0.0194 ± 0.0002 defghi	0.362 ± 0.02 defg
27	Wugu 3861	248 ± 12.5 bc	39.9 ± 6.5 jkl	69.8 ± 1.2 defgh	19.4 ± 0.4 cd	20.8 ± 1.2 bcd	8.87 ± 1.1 cdefghij	55.3 ± 10.1 defghi	4.76 ± 0.4 fgh	0.0155 ± 0.0008 b	0.352 ± 0.04 defgh
28	Xinzhongyu 801	276 ± 8.8 ab	122 ± 19.0 bc	128 ± 8.8 b	11.8 ± 2.3 fg	16.3 ± 2.6 defgh	42.8 ± 6.9 b	704 ± 109 i	57.2 ± 3.8 a	0.0221 ± 0.001 c	3.21 ± 0.4 a
29	Yayu 719	98.1 ± 12.3 hijkl	72.8 ± 11.7 efg	104 ± 8.7 c	6.42 ± 0.7 ijkl	19.7 ± 2.0 cdef	7.49 ± 0.5 defghij	44.0 ± 6.5 efghi	1.56 ± 0.244 kl	0.0116 ± 0.0004 a	0.0255 ± 0.01 defghi

Different letters in each column indicate that the same index has significant differences among different maize varieties ($p < 0.05$).

3.5. Cluster Analysis of Maize Biomass, Grain Bioenrichment Coefficient, Heavy Metal Accumulation, and Extraction Efficiency

3.5.1. Cluster Analysis of the Biomass of Each Part of Maize

The systematic clustering method was used to cluster the biomasses of the 29 maize varieties (in terms of roots, stems, leaves, and grains and in terms of roots, stems, and leaves) (Figure 4). The weights of each part (roots, stems, leaves, and grains) of the 29 maize varieties were divided into three types. The third type (high-biomass type) consists of Qiuqing 88, Jin Yid418, Jin Qiuyu 35, Kangyu 8, Ludan 12, Huidan 936, Wugu 3861, and Kenyu 1505. The second type (medium-biomass type) consists of Qinrui 3817, Longhuangbai 3, Wugu 1790, Tianyan 31, and Tianyan 29. The remaining 16 species were of the low-biomass type (Figure 4a).

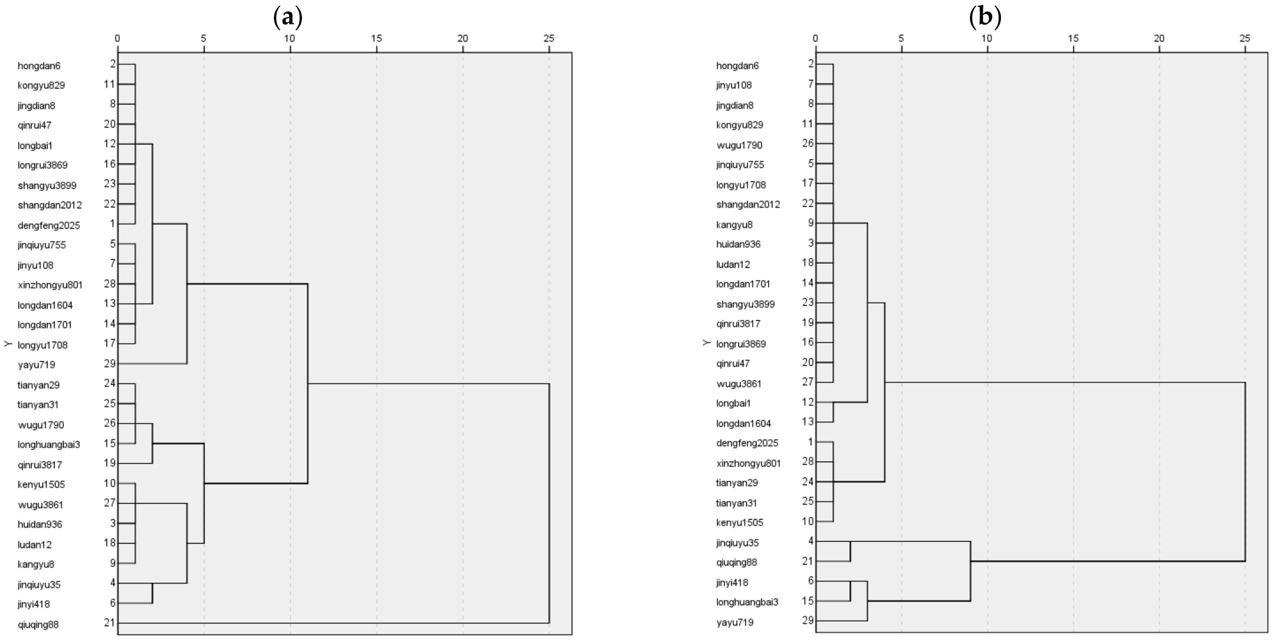

Figure 4. Biomass cluster analysis of each part (**a**) and the roots, stems, and leaves (**b**) of the 29 maize varieties.

The weights of each part (roots, stems, and leaves) of the 29 maize varieties were divided into three types. The third type (high-biomass type of roots, stems, and leaves) consists of Yayu 719, Longhuangbai 3, Jinyin 418, Qiuqing 88, and Jinqiuyu 35. The second type (roots, stems, and leaves biomass type) consists of Kenyu 1505, Tianyan 31, Tianyan 29, Xinzhongyu 801, and Fengdeng 2025. The remaining 19 maize varieties were of the low-biomass removal type of roots, stems, and leaves (Figure 4b).

The biomass weight of each part of maize was significantly different ($p < 0.05$), which was related to the difference in varieties. The cluster analysis of the weight of each part (roots, stems, leaves, and grains) and the roots, stems, and leaves of the maize varieties showed that Qiuqing 88, Jin Yid 418, and Jin Qiuyu 35 are high-biomass types and high-biomass types of roots, stems, and leaves. Kenyu 1505 is a high-biomass type and medium-biomass type of roots, stems, and leaves. Longhuangbai 3 is a medium-biomass type and high-biomass type of roots, stems, and leaves. Tianyan 31 and Tianyan 29 are medium-biomass types and medium-biomass types of roots, stems, and leaves. Kangyu8, Ludan 12, Huidan 936, and Wugu 3861 are high-biomass types and low-biomass types of roots, stems, and leaves. Yayu 719 is a low-biomass type and high-biomass type of roots, stems, and leaves. Qinrui 3817 and Wugu 1790 are medium-biomass types and low-biomass types of roots, stems, and leaves. Xinzhongyu 801 and Fengdeng 2025 are low-biomass types and medium-biomass types of roots, stems, and leaves. The remaining 13 varieties are both low-biomass types and low-biomass types of roots, stems, and leaves.

3.5.2. Cluster Analysis of Maize Grain Bioenrichment Coefficient

The grain bioenrichment coefficients of the 29 maize varieties were analyzed using the systematic clustering method (Figure 5). The biological enrichment of Pb in the 29 maize varieties can be divided into three types. The first type (low-enrichment type) consists of Shangyu 3899, Kangyu 8, Huidan 936, Dengfeng 2025, Jinyu 108, Ludan 12, Yayyu 719, Qinrui 3817, Jinqiuyu 35, Qiuqing 88, Kenyu 1505, and Longyu 1708. The second type (medium-enrichment type) consists of Kongyu 829, Hongdan 6, Jinqiuyu 755, Tianyan 31, Wugu 3861, Jingdian 8, Tianyan 29, Shangdan 2012, Longbai 1, Longrui 3869, Xinzhongyu 801, Longhuangbai 3, and Longdan 1604. The third type (high-enrichment type) consists of Longdan 1701, Jinyi 418, Qinrui 47, and Wugu 1790 (Figure 5a).

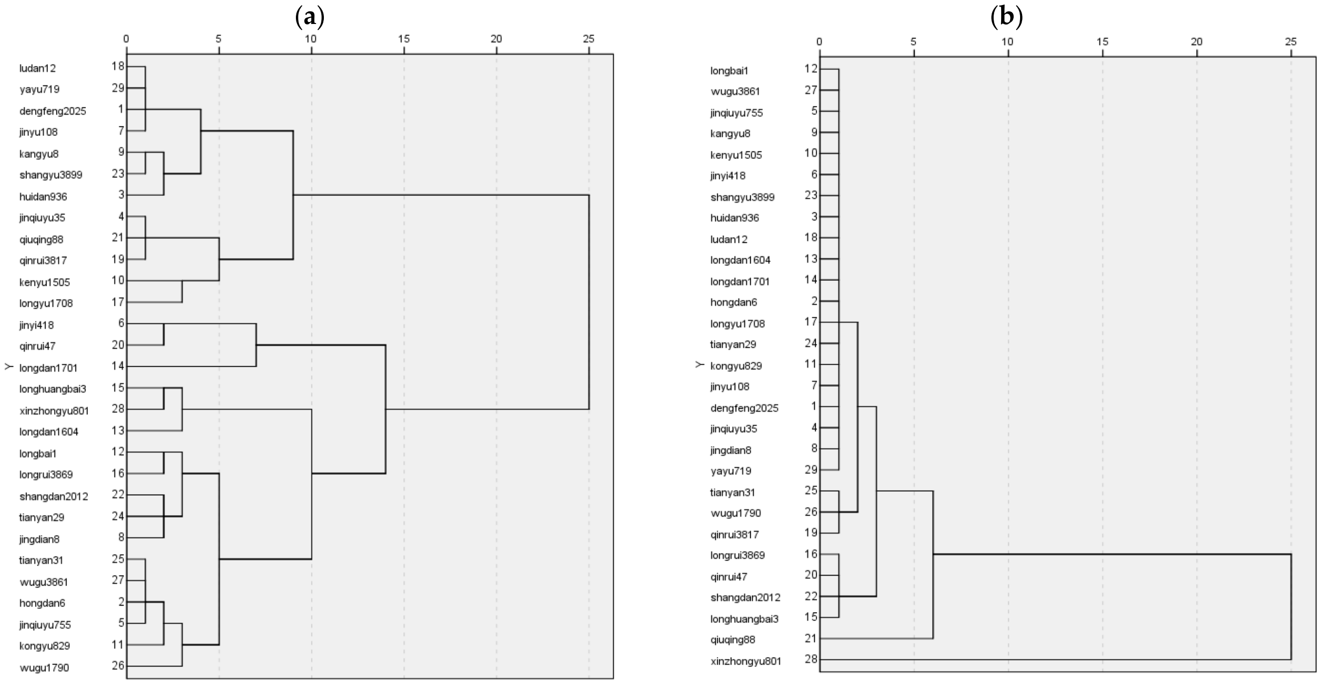

Figure 5. Cluster analysis of lead (**a**) and cadmium (**b**) bioenrichment coefficients in the 29 maize varieties.

The bioenrichment of Cd in the 29 maize varieties was divided into three types. The third type (high-enrichment type) consists of Xinzhongyu 801, Qiuqing 88, Longhuangbai 3, Shangdan 2012, Qinrui 47, and Longrui 3869. The second type (medium-enrichment type) consists of Qinrui 3817, Wugu 1790, and Tianyan 31. The remaining 20 maize varieties are of type I (low-enrichment type) (Figure 5b).

There were significant differences in the contents of the heavy metals, Cd and Pb, in the maize grains (p < 0.05), which were related to the bioenrichment ability of the different maize varieties. The clustering analysis of the heavy metal-enrichment coefficient of Cd and Pb in maize grains showed that Qinrui 47 is a high-enrichment variety of Pb and Cd in maize grains, meaning that it could effectively accumulate Pb and Cd. Xinzhongyu 801, Longhuangbai 3, Shangdan 2012, and Longrui 3869 are medium-Pb-enrichment varieties and high-Cd-enrichment varieties in maize grains. Qiuqing 88 is a low-Pb-enrichment variety and a high-Cd-enrichment variety in maize grains. Wugu 1790 is a high-Pb-enrichment variety and a medium-Cd-enrichment variety in maize grains. Tianyan 31 is a medium-enrichment variety for Pb and Cd in maize grains. Zhenrui 3817 is a low-Pb-enrichment variety and a medium-Cd-enrichment variety in maize grains. Longdan 1701 and Jinyid 418 are high-Pb-enrichment varieties and low-Cd-enrichment varieties in maize grains. Kongyu 829, Hongdan 6, Jinqiuyu 755, Wugu 3861, Jingdian 8, Tianyan 29, Longbai 1, and Longdan 1604 are medium-Pb-enrichment varieties and low-Cd-enrichment varieties. Shangyu 3899, Kangyu 8, Huidan 936, Dengfeng 2025, Jinyu 108, Ludan 12, Yayu 719, Qinrui 3817, Jinqiuyu 35, Kenyu 1505, and Longyu 1708 are the low-enrichment varieties of Pb in maize grains and Cd.

3.5.3. Cluster Analysis of Heavy Metal Accumulation in Each Part of Maize (Roots, Stems, and Leaves)

The accumulation of Pb and Cd in each part (roots, stems, and leaves) of the 29 maize varieties was analyzed using the systematic clustering method (Figure 6). Pb accumulation in all parts (roots, stems, and leaves) of the 29 maize varieties could be divided into three types. The first type (high-accumulation type) consists of Jin Yi 418, Xinzhongyu 801, Hongdan 6, and Wugu 1790. The second type (medium-accumulation type) consists of Wugu 3861, Kangyu 8, Longdan 1604, Longbai 1, Kenyu 1505, Qinrui 3817, Yayu 719, Huidan 936, Fengdeng 2025, and Qinrui 47. The third type (low-accumulation type) consists of Tianyan 31, Shangyu 3899, Ludan 12, Jinyu 108, Shangdan 2012, Tianyan 29, Longrui 3869, Longyu 1708, Longhuangbai 3, Longdan 1701, Jinqiuyu 35, Jingdian 8, Jinqiuyu 755, Qiuqing 88, and Kongyu 829 (Figure 6a).

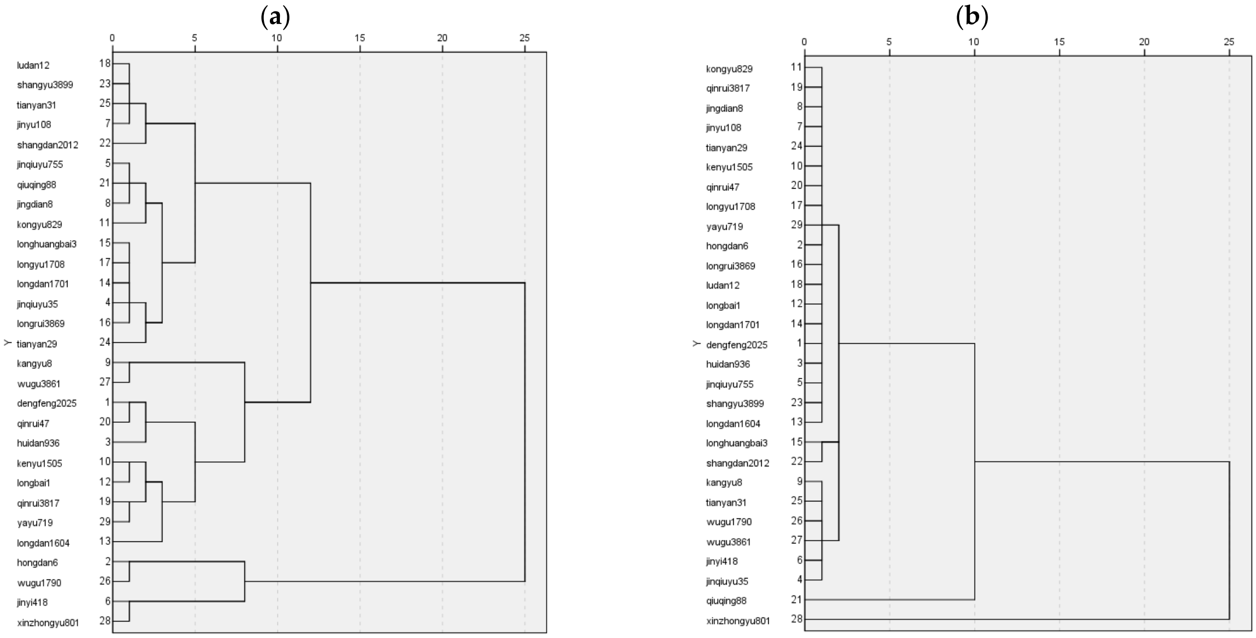

Figure 6. Cluster analysis of lead (**a**) and cadmium (**b**) accumulation in stems and leaves (roots, stems, and leaves) of 29 maize varieties.

The accumulation of Cd in each part (roots, stems, and leaves) of the 29 maize varieties could be divided into three types. The first type (high-accumulation type) consists of Xinzhongyu 801 and Qiuqing 88. The second type (medium-accumulation type) consists of Shangdan 2012, Longhuangbai 3, Jinqiuyu 35, Jinyid 418, Tianyan 31, Kangyu 8, Wugu 3861, and Wugu 1790. The remaining 19 species are of the third type (low-accumulation type) (Figure 6b).

The accumulation of Cd and Pb heavy metals in different parts of maize (roots, stems, and leaves) differed significantly ($p < 0.05$), which was related to the accumulation ability of Cd and Pb heavy metals in different varieties. The cluster analysis of the heavy metal accumulation of Cd and Pb in each part (roots, stems, and leaves) showed that Xinzhongyu 801 was a high-accumulation type of Pb and Cd, and its roots, stems, and leaves had a strong accumulation capacity for Pb and Cd. Qiuqing 88 is a low-accumulation-type variety of Pb and a high-accumulation-type variety of Cd. Jinyi 418 and Wugu 1790 are the high-accumulation-type varieties of Pb and the medium-accumulation-type varieties of Cd. Hongdan 6 is a high-accumulation-type variety of Pb and a low-accumulation-type variety of Cd. Wugu 3861 and Kangyu 8 are the medium-accumulation-type varieties of Pb and Cd in maize. Shangdan 2012, Longhuangbai 3, Jinqiuyu 35, and Tianyan 31 are the low-accumulation-type varieties of Pb and the medium-accumulation-type varieties of Cd. Longdan 1604, Longbai 1, Kenyu 1505, Qinrui 3817, Yayu 719, Huidan 936, Fengdeng 2025, and Qinrui 47 are the medium-accumulation-type varieties of Pb and the low-accumulation-type varieties of Cd. The remaining 10 maize varieties are Pb and Cd low-accumulation-type varieties.

3.5.4. Cluster Analysis of Heavy Metal Extraction Efficiency of Maize

The extraction efficiency of Pb and Cd in the 29 maize varieties was analyzed using the systematic clustering method (Figure 7). The Pb extraction efficiency of the 29 maize varieties can be divided into three types. The first type (high-extraction type) consists of Jin Yi418, Xinzhongyu 801, Wugu 1790, and Hongdan 6. The second type (medium-extraction type) consists of Wugu 3861, Kangyu 8, Longdan 1604, Longbai 1, Kenyu 1505, Qinrui 3817, Yayu 719, Huidan 936, Qinrui 47, and Dengfeng 2025. The remaining maize varieties are of the third type (low-extraction type) (Figure 7a).

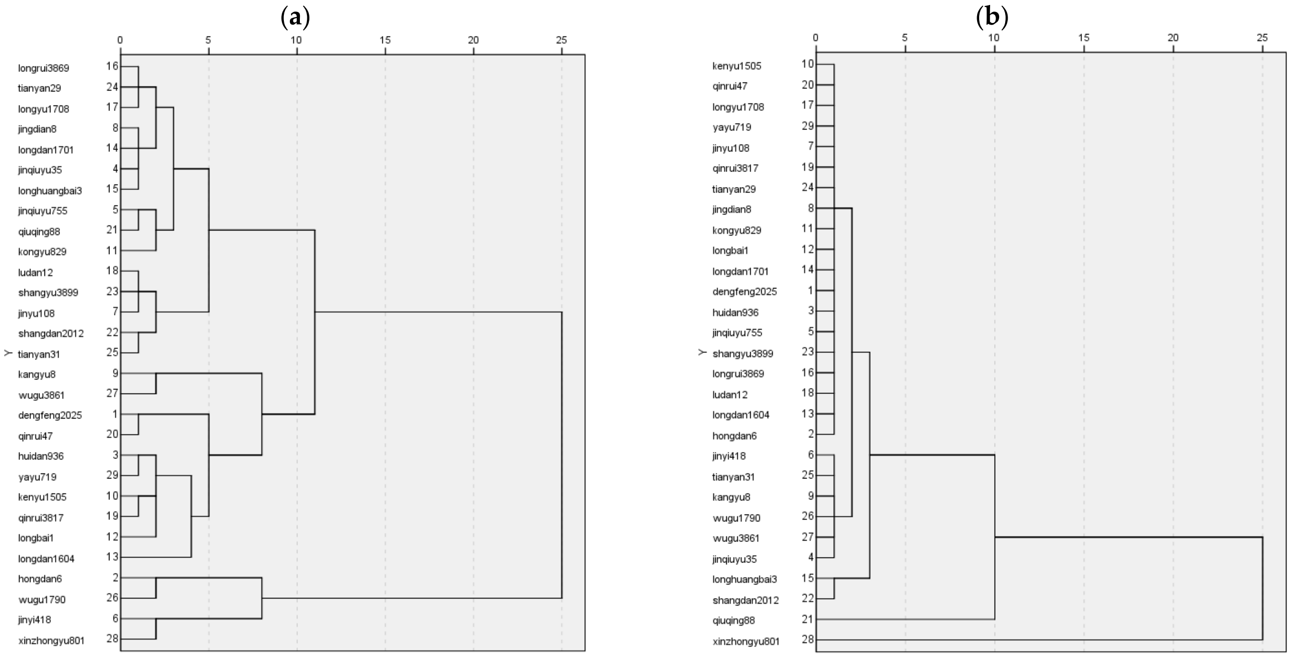

Figure 7. Clustering analysis of extraction efficiency of lead (**a**) and cadmium (**b**) in stems and leaves of the 29 maize varieties.

The Cd extraction efficiency of the 29 maize varieties can be divided into three types. The first type (high-extraction type) of maize varieties consists of Xinzhongyu 801 and Qiuqing 88. The second type (medium-extraction type) of maize varieties consists of Shangdan 2012, Longhuangbai 3, and Jinqiuyu 35. The remaining maize varieties are of the third type (low-extraction type) (Figure 7b).

There were significant differences in the extraction efficiency of Cd and Pb from maize ($p < 0.05$), which was related to the Cd and Pb extraction ability of different varieties. The cluster analysis of the heavy metal extraction efficiency of Cd and Pb showed that Xinzhongyu 801 is a high-extraction type regarding Pb and Cd in maize. Qiuqing 88 is a low-extraction type for Pb and a high-extraction type for Cd. Jinyid418, Wugu 1790, and Hongdan 6 are high-extraction types for Pb and low-extraction types for Cd. Shangdan 2012, Longhuangbai 3, and Jinqiuyu 35 are low-extraction types for Pb and medium-extraction types for Cd. Wugu 3861, Kangyu 8, Longdan 1604, Longbai 1, Kenyu 1505, Qinrui 3817, Yayu 719, Huidan 936, Qinrui 47, and Dengfeng 2025 are medium-extraction types for Pb and low-extraction types for Cd. The other 11 varieties are low-extraction types for Pb and Cd from maize stalk and leaf.

4. Discussion

4.1. Selection of Varieties with High Biomass and Low Accumulation of Heavy Metals

The varieties with high biomass and low accumulation of the heavy metal Pb are Kangyu 8, Huidan 936, and Kenyu 1505. There are four varieties with high biomass and low accumulation of the heavy metal Cd: Jinyid418, Jinqiuyu 35, Kangyu 8, and Wugu 3861. It can, thus, be concluded that Kangyu 8 is of the high-biomass and low-accumulation type regarding both the heavy metals Pb and Cd. Grain Pb contents were associated with leaves and ear Pb contents [27]. The high-biomass and low-accumulation type maize varieties have high biomass; medium–high accumulation of heavy metals in roots, stems, and leaves; and low accumulation of heavy metals in grains, which means that they are suitable for the long-term restoration and safe utilization of medium and lightly polluted cultivated land. The results indicate that the vegetative parts are more susceptible to soil metals than the reproductive parts [28]. Under the same planting conditions, the biomass of maize is higher, and heavy metals accumulate in the roots, stems, and leaves; as a result, more heavy metals can be removed from the soil, thus achieving soil remediation during maize production [29]. The purpose of soil restoration can be achieved through the collection and treatment of straw. However, the grain-enrichment capacity is low, and it does not exceed the threshold value of the Pb 0.2 mg/kg, Cd 0.1 mg/kg [22], which can ensure the food safety of maize.

4.2. Selection of Maize Varieties with High Accumulation of Heavy Metals

The maize variety Xinzhongyu 801 is a high-extraction type for the heavy metal Pb. The high-extraction maize varieties for heavy metal Cd consist of Xinzhongyu 801 and Qiuqing 88. It can thus be concluded that Xinzhongyu 801 is a high-extraction type for both heavy metals Pb and Cd. The heavy metal extraction rate of high heavy metal extraction type maize varieties is high. Heavy metals easily accumulate in the grain, which poses potential risks to livestock and human health; thus, such varieties are not suitable for feed or food. Therefore, it is not recommended to plant them in the surrounding area of lead and zinc smelting enterprises. The order of the maize enrichment quantity was Zhenghong 6 (0.26 mg/strain) > Chuandan13 = Yayu 12 (0.21 mg/strain) > Nongda 95 (0.20 mg/strain). We found that Zhenghong 6, Yayu 12, and Nongda 95 can be used as the preferred maize for soil remediation [30]. Liao et al.'s study elucidated the gene function of the ZmHMA3 response to Cd and Zn stress and provides a reference for improving the characteristics of heavy metal enrichment in existing maize varieties and plant remediation technology of heavy metal-contaminated soil [31].

4.3. Selection of Forage Maize Varieties

The heavy metal Pb feed-maize varieties are Qiuqing 88, Jinqiuyu 35, and Ludan 12. These forage-maize varieties have high biomass, and the heavy metal contents in all parts (roots, stems, leaves, and grains) did not exceed the minimum threshold of Pb 5 mg/kg, Cd 0.5 mg/kg [23], with low heavy metal accumulation capacity [20]. Therefore, it is suggested that these varieties could be used as feed raw materials.

4.4. Selection of Maize Varieties with Low Heavy Metal Accumulation

The heavy metal Pb low-accumulation-type maize varieties are Jinqiuyu 35, Jinqiuyu 755, Jinyu 108, Longdan 1701, Longhuangbai 3, Longrui 3869, Ludan 12, Qiuqing 88, Shangdan 2012, Shangyu 3899, Tianyan 29, Tianyan 31, and another 12. Maize varieties with a low accumulation of heavy metals have a low accumulation of both Pb and Cd; therefore, these varieties can be safely used in medium- and low-polluted farmland [32] (Figure 8).

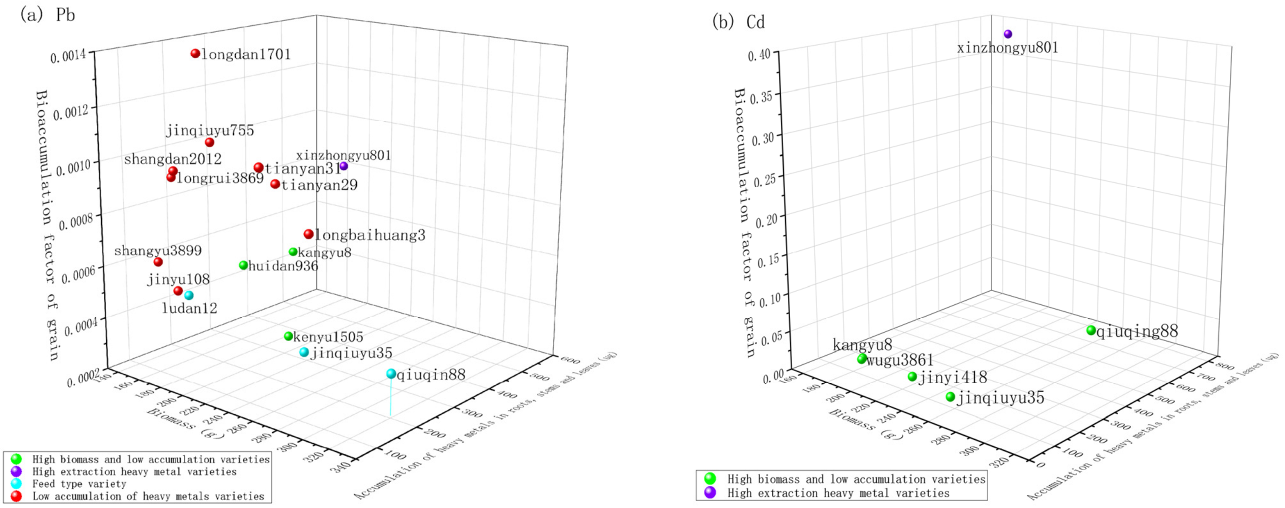

Figure 8. Screening and classification results of the 29 maize varieties: Pb (**a**) and Cd (**b**).

5. Conclusions

Significant differences in the plant height, biomass, and yield of the 29 maize varieties were found under the condition of combined Pb and Cd pollution caused by atmospheric deposition around typical Pb and Zn smelting enterprises ($p < 0.05$). The effects of heavy metals on the growth of Longhuangbai 3, Jinqiuyu 35, Jinyi 418, and Qiuqing 88 were minimal. The ability of metal enrichment and transport in different parts of maize is very different. The contents of Pb and Cd in maize varieties usually follow the order of leaf > stem > root > grain. According to the extraction efficiency of Pb and Cd and the content of heavy metals in the grain, the 29 maize varieties were divided into four categories: (1) the first type could be applied to soil remediation and safe production, including Qiuqing 88 (Pb, Cd), Fengdeng 2025 (Cd), and Yayu 719 (Pb, Cd); (2) the second type includes varieties where the metal content in the edible parts was higher but did not exceed the national feed health standards, such as Jin Yid 418 (Pb), Shangdan 2012 (Pb), Tianyan 29 (Pb), Tianyan 31 (Pb), Wugu 1790 (Pb), and Wugu 3861 (Pb); (3) the third category comprises metal-repellent varieties, including Kanyu 1505 (Pb, Cd); and (4) the fourth type, including varieties Xinzhongyu 801 (Cd) and Longdan 1701 (Pb), shows high accumulation of metals in their edible parts, posing a potential risk to human health. Therefore, it is not recommended to grow these varieties locally.

Author Contributions: Conceptualization, methodology, investigation, resources, data curation, project administration, formal analysis, and writing—original draft preparation: P.Z., S.H., M.Y. and X.Z. Data curation, project administration, and writing—review and editing: M.W. and L.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science and Technology Talents and Platform Program (Academician and Expert Workstation) (202205AF150010).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pott, U.; Turpin, D.H. Assessment of Atmospheric Heavy Metals by Moss Monitoring with Isothecium Stoloniferum Brid. in the Fraser Valley, B.C. Canada. *Water Air Soil Pollut.* **1998**, *101*, 25–44. [CrossRef]
2. Li, J.H. Soil Remediation of Heavy Metal Contaminated Farmland in a Mine in Yunnan Engineering Demonstration. Ph.D. Thesis, Nanjing Agricultural University, Nanjing, China, 2019.

3. Tong, S.; Yang, L.; Gong, H.; Wang, L.; Li, H.; Yu, J.; Li, Y.; Deji, Y.; Nima, C.; Zhao, S.; et al. Bioaccumulation characteristics, transfer model of heavy metals in soil-crop system and health assessment in plateau region, China. *Ecotoxicol. Environ. Saf.* **2022**, *241*, 113733. [CrossRef]
4. Xie, T.; Shi, Z.; Gao, Y.; Tan, L.; Meng, L. Modeling analysis of the characteristics of selenium-rich soil in heavy metal high background area and its impact on main crops. *Ecol. Inform.* **2021**, *66*, 101420. [CrossRef]
5. Liu, R.P.; Xu, Y.N.; Zhang, J.H.; Wang, W.K.; Elwardany, R.M. Effects of heavy metal pollution on farmland soils and crops: A case study of the Xiaoqinling Gold Belt, China. *China Geol.* **2020**, *3*, 402–410.
6. Masona, C.; Mapfaire, L.; Mapurazi, S.; Makanda, R. Assessment of Heavy Metal Accumulation in Wastewater irrigated Soil and Uptake by Maize plants (*Zea mays* L.) at Firle Farm in Harare. *J. Sustain. Dev.* **2011**, *4*, 132–137. [CrossRef]
7. Singh, R.; Singh, P.K.; Madheshiya, P.; Khare, A.K.; Tiwari, S. Heavy Metal Contamination in the Wastewater Irrigated Soil and Bioaccumulation in Cultivated Vegetables: Assessment of Human Health Risk. *J. Food Compos. Anal.* **2024**, *128*, 106054. Available online: http://gfbfh81f8000da3924570s006oq6k6ow9f6oqw.fgac.kust.cwkeji.cn/10.1016/j.jfca.2024.106054 (accessed on 4 February 2024). [CrossRef]
8. Moradi, A.; Honarjoo, N.; Najafi, P.; Fallahzade, J. A human health risk assessment of soil and crops contaminated by heavy metals in industrial regions, central Iran. *Hum. Ecol. Risk Assess.* **2016**, *22*, 153–167. [CrossRef]
9. Girum, H.; Nibret, M.; Gulelat, D.; Girma, K. Heavy metal contamination and health risk assessment of horticultural crops in two sub-cities of Addis Ababa, Ethiopia. *Toxicol. Rep.* **2023**, *11*, 420–432.
10. Wan, M.; Hu, W.; Wang, H.; Tian, K.; Huang, B. Comprehensive assessment of heavy metal risk in soil-crop systems along the Yangtze River in Nanjing, Southeast China. *Sci. Total Environ.* **2021**, *780*, 146567. [CrossRef] [PubMed]
11. Kharazi, A.; Leili, M.; Khazaei, M.; Alikhani, M.Y.; Shokoohi, R. Human health risk assessment of heavy metals in agricultural soil and food crops in Hamadan, Iran. *J. Food Compos. Anal.* **2021**, *100*, 103890. [CrossRef]
12. Wang, X.; Li, W.; Wang, D.; Wu, S.; Yan, Z.; Han, J. Trinity assessment method applied to heavy-metal contamination in peri-urban soil–crop systems: A case study in northeast China. *Ecol. Indic.* **2021**, *132*, 108329. [CrossRef]
13. Xiang, M.; Li, Y.; Yang, J.; Lei, K.; Li, Y.; Li, F.; Zheng, D.; Fang, X.; Cao, Y. Heavy metal contamination risk assessment and correlation analysis of heavy metal contents in soil and crops. *Environ. Pollut.* **2021**, *278*, 116911. [CrossRef] [PubMed]
14. Nawab, J.; Khan, S.; Shah, M.T.; Gul, N.; Ali, A.; Khan, K.; Huang, Q. Heavy Metal Bioaccumulation in Native Plants in Chromite Impacted Sites: A Search for Effective Remediating Plant Species. *Clean-Soil Air Water* **2016**, *44*, 37–46. [CrossRef]
15. Hu, P.; Tu, F.; Li, S.; Pan, Y.; Kong, C.; Zhang, X.; Wang, S.; Sun, Y.; Qiu, D.; Wu, L.; et al. Low-Cd wheat varieties and soil Cd safety thresholds for local soil health management in south Jiangsu province, east China. *Agric. Ecosyst. Environ. Int. J. Sci. Res. Relatsh. Agric. Food Prod. Biosph.* **2023**, *341*, 108211. [CrossRef]
16. Zhang, K.; Ding, S.; Yan, Y.; Huang, X.; Li, S.; Zhao, W.; Chen, X.; Dai, J. Screening of peanut cultivars with low-cadmium accumulation assisted by cadmium resistance: Promoting safe utilization of cadmium contaminated soils. *Appl. Soil Ecol.* **2024**, *193*, 105109. [CrossRef]
17. Hu, Z.; Wang, Y.; Fang, Z.; Shi, G.; Lou, L.; Ren, K.; Cai, Q. Italian ryegrass-rice rotation system for biomass production and cadmium removal from contaminated paddy fields. *Soils Sediments* **2020**, *20*, 874–882. [CrossRef]
18. Xu, M.; Yang, L.; Chen, Y.; Jing, H.; Wu, P.; Yang, W. Selection of rice and maize varieties with low cadmium accumulation and derivation of soil environmental thresholds in karst. *Ecotoxicol. Environ. Saf.* **2022**, *247*, 114244. [CrossRef] [PubMed]
19. Mancinelli, R.; Radicetti, E.; Muleo, R.; Marinari, S.; Bravo, I.; Papetti, P. Can Hairy Vetch Cover Crop Affects Arsenic Accumulation in Vegetable Crops? *Agriculture* **2019**, *9*, 89. [CrossRef]
20. Yang, N.; Wang, H.; Wang, H.; Wang, Z.; Ran, J.; Guo, S.; Peng, Y. Screening maize (*Zea mays* L.) varieties with low accumulation of cadmium, arsenic, and lead in edible parts but high accumulation in other parts: A field plot experiment. *Environ. Sci. Pollut. Res.* **2021**, *28*, 33583–33598. [CrossRef]
21. Zha, Y.; Zhao, L.; Niu, T.; Yue, E.; Wang, X.; Shi, J. Multi-Target Element-Based Screening of Maize Varieties with Low Accumulation of Heavy Metals (HMs) and Metalloids: Uptake, Transport, and Health Risks. *Agriculture* **2023**, *13*, 1123. [CrossRef]
22. *GB 2762-2022*; National Standard for Food Safety Food Pollutant Limit. National Health Commission of the People's Republic of China, State Administration for Market Regulation: Beijing, China, 2022.
23. *GB 13078-2017*; Hygienical Standard for Feeds. General Administration of Quality of Quality Supervision. Inspection and Quarantine of the People's Republic of China, Standardization Administration: Beijing, China, 2017.
24. Shahid, M.; Dumat, C.; Khalid, S.; Schreck, E.; Xiong, T.; Niazi, N.K. Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. *J. Hazard. Mater.* **2017**, *325*, 36–58. [CrossRef]
25. Anjum, S.A.; Tanveer, M.; Hussain, S.; Shahzad, B.; Ashraf, U.; Fahad, S.; Hassan, W.; Jan, S.; Khan, I.; Saleem, M.F.; et al. Osmoregulation and antioxidant production in maize under combined cadmium and arsenic stress. *Environ. Sci. Pollut. Res.* **2016**, *23*, 11864–11875. [CrossRef] [PubMed]
26. Cao, F.; Cai, Y.; Liu, L.; Zhang, M.; He, X.; Zhang, G.; Wu, F. Differences in photosynthesis, yield and grain cadmium accumulation as affected by exogenous cadmium and glutathione in the two rice genotypes. *Plant Growth Regul.* **2015**, *75*, 715–723. [CrossRef]
27. Ashraf, U.; Mahmood, M.H.U.R.; Hussain, S.; Abbas, F.; Anjum, S.A.; Tang, X. Lead (Pb) distribution and accumulation in different plant parts and its associations with grain Pb contents in fragrant rice. *Chemosphere* **2020**, *248*, 126–133. [CrossRef]
28. Ching, J.A.; Binag, C.A.; Alejandro, G.J.D. Uptake and distribution of some heavy metals in peanut (*Arachis hypogaea* L.) grown in artificially contaminated soils. *Philipp. Agric.* **2009**, *91*, 134–142.

29. Chen, W.; Kang, Z.; Yang, Y.; Li, Y.; Qiu, R.; Qin, J.; Li, H. Interplanting of rice cultivars with high and low Cd accumulation can achieve the goal of "repairing while producing" in Cd-contaminated soil. *Sci. Total Environ.* **2022**, *851*, 158229. [CrossRef]
30. Yuan, L.; Liu, Y.; Lan, Y.S. Variations of Cadmium Absorption and Accumulation among Corn Cultivars of Metal Pollution in Soil from Lead-Zinc Mining Area. *J. Sichuan Agric. Univ.* **2018**, *36*, 6. [CrossRef]
31. Liao, C.; Li, Y.; Wu, X.; Wu, W.; Zhang, Y.; Zhan, P.; Meng, X.; Hu, G.; Yang, S.; Lin, H. ZmHMA3, a Member of the Heavy-Metal-Transporting ATPase Family, Regulates Cd and Zn Tolerance in Maize. *Int. J. Mol. Sci.* **2023**, *24*, 13496. [CrossRef]
32. Zhang, C.H.; Wang, Z.S.; Liu, L.; Liu, Y. Comprehensive Quality Assessment of Soil-Maize Heavy Metals in High Geological Background Area. *Environ. Sci.* **2023**, *44*, 4142–4150.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.