

Diagnosis and Integrated Assessment of Maize Health and Associated Soil

Weishun Cheng[#], Xi Luo[#], Guiyou Zhang, Juhong Zhu, Suping Wang^{*}, Lei Du^{*}

Institute of Environment and Safety, Wuhan Academy of Agricultural Science, Wuhan, Hubei, China

[#]Theses authors contribute equally to this work

^{*}Corresponding Author

Abstract: The soil and maize quality of three maize planting bases in Wuhan were investigated and evaluated by single factor index method and modified Nemerow Comprehensive Index method. The results showed that the pH values of the three sites were weak acidic, the organic matter content was high, the levels of other major nutrients were unbalanced, and the micronutrient levels were relatively low. The comprehensive fertility is general. The single pollution index of heavy metals was $P < 1$, the Order of pollution sharing rate was: lead (35.83%) > arsenic (19.26%) > mercury (16.06%) > chromium (15.23%) > cadmium (5.39%) > copper (3.66%) > DDT(2.28%) > BHC(2.10%), comprehensive pollution index $P = 0.29 < 0.7$, is a safety level, for the clean level, in line with national standards. The contents of heavy metals and organic pesticides in maize seeds were lower than the green industry standard, and the enrichment ability of organic pesticides was stronger, the contents of heavy metals As, Pb, Cr and DDT in maize seeds were significantly correlated with the contents in soil, with correlation coefficients of 0.924, 0.852, 0.90 and 0.843, respectively.

Keywords: Maize; Fertility of Soil; Heavy Metals; Organic Pesticides; Integrative Assessment

1. Introduction

Corn is the main grain and feed crop in China. The area planted in the whole country is over $2 \times 10^7 \text{hm}^2$. The area planted in Hubei is over $4.3 \times 10^5 \text{hm}^2$, accounting for about 2% of the total area planted in the whole country, the country's total output accounts for about 2% [1]. According to the growth law of maize and the requirement of environment, 80% of the land area in Hubei is suitable for maize planting. At

present, maize cultivation in Hubei is mainly divided into four regions, namely the mountainous region in northwest Hubei, the maize region in Jiangnan Plain, the hilly region in eastern Hubei and the summer maize region in northern Hubei. Wuhan is part of the Jiangnan Plain Corn region, with about $33,000 \text{hm}^2$ of corn area planted, accounting for about 8% of the province's corn area. The average yield per unit area is 1200kg/hm^2 higher than the average level of the whole province, which belongs to the high yield area in the whole province [2].

In recent years, with the improvement of living standard, people pay more attention to the quality and safety of agricultural products. Therefore, the production of high-quality and pollution-free agricultural products has become the direction of the development of agricultural products, and soil environmental quality is one of the main factors affecting the quality and safety of agricultural products [3]. The deterioration of soil environment is a common problem in crop cultivation. With the increase of cultivation age or continuous cropping in the cultivated land, most of the crops suffer from poor growth, and their quality and yield decrease greatly. The deterioration of soil quality is mainly manifested in the following two points: first, the lack of soil nutrients. After the crops absorb a large amount of some special nutrient elements, it will cause the partial consumption of soil nutrients, make the soil nutrient elements lose balance and cause the deficiency of some nutrient elements, and the change of soil acidity and alkalinity. In the continuous cultivation of crops for many years, less and less elements are needed for the growth and development of plants in the soil, make the soil acidity and alkalinity out of balance, then cause the single salt poison [4,5].

The formation of maize quality is affected by many factors, among which the soil factor is paid more and more attention. The corn absorbs

the water and nutrients it needs from the soil. If the soil environment is polluted, the pollutants will enter the corn through this route, therefore, the quality of soil environment has become an important limiting factor in the formation of maize quality, and is also one of the key problems to be solved in the process of maize cultivation. Modern science has demonstrated that pesticide residues and heavy metals can enter the body along the food chain and bind firmly to enzyme proteins, impairing the structure and function of tissue cells [6]. At present, many studies have shown that different crops due to bio-accumulation of organic pesticides problem [7]. The present situation of maize soil environmental quality in Wuhan was investigated and analyzed in this paper, and the soil environmental quality was evaluated.

2. Materials and Methods

Soil samples were taken from Hannan base, Dongxihu base and Caidian District base. Soil sampling shall be carried out in accordance with the provisions of GB15618 and shall be representative, accurate, reasonable and scientific in nature. Soil samples shall be taken from potential contaminated sites, the soil type is yellow-brown soil. Three random sampling areas were set up in each of the three bases, and 5 soil samples of 0~20cm tilling layer were collected by serpentine sampling method in each sampling area. Soil samples collected in the laboratory air-dry, remove impurities, screening, bottling to be tested.

Samples of corn kernels were collected from the three bases of Hannan, Dongxihu and Caidian District in early summer. The corn grains were soaked in water and dried. Some of them were crushed and dehydrated to constant weight, set aside in the dryer.

Soil nutrients were determined by conventional methods pH by pH meter, organic matter by potassium dichromate heating, alkaline hydrolysis and diffusion of alkaline nitrogen, available phosphorus by Tian[8], available potassium by leaching with neutral ammonium acetate and flame photometer; Available calcium, magnesium, copper, zinc, iron and manganese were extracted with DTPA-atomic absorption photometer. In addition, according to the requirements of pollution-free products on soil environmental quality, 8 indexes of Mercury, arsenic, lead, cadmium, chromium, copper, BHC and DDT were analyzed according to relevant

national standards.

The evaluation standard of soil environmental quality is based on the pollutant control index recommended by agricultural industry standard; The evaluation method and classification standard were evaluated according to the single pollution index recommended by the national standard and the comprehensive pollution index method of Nemerow.

The single pollution index = the measured value of a certain kind of dye in the soil/the evaluation standard of the dye in the soil.

Composite Pollution Index = $\text{SQRT} \{[(\text{average single pollution index})^2 + (\text{maximum single pollution index})^2]/2\}$, the SQRT in the formula is the square root, the classification standard of soil comprehensive pollution index is as Table 1, According to the comprehensive fertility coefficient (P) calculated by the modified Nemoro formula [9], the soil fertility evaluation index is given, and the classification standard of soil grade is as Table 2.

Table 1. Standard for Levels of Polluted Soils

Soil grade	Comprehensive pollution index (Pc)	Pollution level
1	$Pc \leq 0.7$	Safe
2	$0.7 < Pc \leq 1.0$	Cordon
3	$1.0 < Pc \leq 2.0$	Light pollution
4	$2.0 < Pc \leq 3.0$	Moderate pollution
5	$Pc > 3.0$	Heavy pollution

Table 2. Classifying Criteria of Soil Quality Gradation

Quality grade	First class	Second class	Third class	Fourth class
Quality reviews	Very fertile	Fertile	General	Barren
Quality index range	≥ 2.8	1.8~2.7	0.9~1.8	< 0.8

Statistical software WPS 2010 were used to calculate and analyze the experimental data.

3. Results and Discussion

Table 3 and table 4 are the diagnosis of single index of soil fertility in maize bases, according to the critical index established by the method of systematic study of soil nutrient status and the second soil census standard of China, the diagnosis and analysis of soil fertility in maize base were carried out. The soil pH value of maize base is 5.7 ~ 6.4, which is weak acid, and the optimum pH value of maize growth is 5.8 ~ 7.5. The content of soil organic matter is 35 ~ 48 g/kg, which is higher than that of maize base In addition, the content of available phosphorus in Hannan base was 18 mg/kg, and the rest was

between 6 mg/kg and 7 mg/kg, and the content of available potassium in Hannan base was only 86 mg/kg, the rest were all in the range of 116 ~ 187 mg/kg. The micronutrient nutrients in the micronutrient soils were low in calcium and magnesium in all the soil samples. According to the ASI (U.S. International Agricultural Service) critical index for soil nutrients (zinc, iron, manganese), the soil of all corn bases is rich in zinc, low in manganese and deficient in iron. The results of comprehensive evaluation of soil fertility in maize base are shown in table 5. According to the comprehensive fertility coefficient (p) calculated by the modified Nemoro formula, the soil fertility evaluation index is given (Table 2). Hannan base and east

and West Lake Base are close to 1.8, relatively fertile, Caidian District base soil fertility level is average. Therefore, it is necessary to apply fertilizer reasonably according to the growing characteristics and requirements of maize.

Table 3. Basic Nutrient Status of Soil in Maize Base

Location	pH	Organic matter (g·kg ⁻¹)	Hydrolyzed nitrogen (mg·kg ⁻¹)	Available phosphorus (mg·kg ⁻¹)	Quick-acting potassium (mg·kg ⁻¹)
Hannan	6.14	35.11	138.39	18.01	86.07
Dongxihu	0.33	45.06	195.72	6.23	187.54
Caidian	6.17	42.34	219.74	5.12	160.09

Table 4. The Micronutrient Nutrient Content of the Maize Base(mg·kg⁻¹)

Location	Ca	Mg	Zn	Fe	Mn
Hannan	100.14	58.21	3.64	0.08	34.91
Dongxihu	110.28	35.41	6.99	0.09	30.62
Caidian	140.22	63.08	8.74	0.09	35.33

Table 5. Evaluation Results of Soil Quality

Location	pH	Organic matter(g·kg ⁻¹)	Hydrolyzed nitrogen(mg·kg ⁻¹)	Available phosphorus(mg·kg ⁻¹)	Quick-acting potassium(mg·kg ⁻¹)	Pi
Hannan	2.64	3.02	2.31	2.80	2.24	1.99
Dongxihu	2.81	3.11	3.00	1.23	2.88	1.65
Caidian	2.60	3.00	3.00	1.01	2.60	1.51

Table 6. Residuals of Heavy Metals in Soil(mg·kg⁻¹)

Location	Index	Hg	As	Pb	Cd	Cr	Cu	BHC	DDT
Hannan	Average	0.03	9.91	40.32	0.02	23.21	1.62	0.01	0.02
	Single pollution index	0.10	0.33	0.81	0.08	0.19	0.03	0.03	0.03
	Composite pollution index	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Dongxihu	Average	0.07	3.81	9.37	0.02	21.08	1.06	0.01	0.01
	Single pollution index	0.22	0.13	0.19	0.06	0.18	0.02	0.01	0.02
	Composite pollution index	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Caidian	Average	0.06	5.35	9.44	0.01	16.01	3.36	0.01	0.01
	Single pollution index	0.22	0.18	0.19	0.04	0.13	0.07	0.03	0.02
	Composite pollution index	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Table 7. The General Environmental Quality of Soil(mg·kg⁻¹)

Monitoring indicator	Hg	As	Pb	Cd	Cr	Cu	BHC	DDT
Average	0.05	6.36	19.71	0.02	20.01	2.01	0.01	0.01
Single pollution index	0.18	0.21	0.39	0.06	0.17	0.04	0.02	0.03
Pollution sharing rate(%)	16.06	19.26	35.83	5.39	15.23	3.66	2.10	2.28
Composite pollution index	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29

According to Table 6 and Table 7, the single pollution index of HG, As, Pb, Cd, Cr, Cu and total BHC and DDT were less than 1, the comprehensive pollution index was far less than 0.7. Compared with the limit value listed in GB15618-1995, the soil pollution level of corn planting base was classified as safe level, and the pollution level was classified as clean level. The content of total BHC and total DDT was low for two reasons: one was that new pesticides, especially biological pesticides, had replaced the original high-toxic and difficult-to-degrade pesticides, and the residual organic pesticides decreased through their own decay residues; Second, the maize planting base pays attention to the soil fertility renewal, increases the organic fertilizer, improves the soil structure, promotes

the organic pesticide's microorganism degradation and the hydrolysis. There are two main reasons for the low content of heavy metals in soil: one is that the natural content of heavy metals in maize growing areas is low, which has no significant adverse effect on maize seed production; The three wastes formed by industrial production are less and light to environment pollution [10].

From Table 8, it can be seen that the total BHC and total DDT residues in the corn kernels produced in the base were lower than the maximum limits of each index in the food green industry standard, and HG was not detected in the Hannan base, total DDT was not detected in the east and West Lake Base, and total BHC was not detected in the Caidian District base,

indicating that the impact of organic pesticides on maize quality was very low. Cr is not included in the food green industry standard, and all other heavy metal indexes except Cr are within the limit. According to the residues of heavy metals and organic pesticides in corn kernels, it has reached the standard of food production. The residues of organic pesticides in maize seeds were significantly higher than that in soil, which indicated that maize seeds had bioaccumulation effect on the residues of organic pesticides in soil. This is mainly due to the organic pesticides BHC and DDT can be

absorbed by plants in the soil residues, and a considerable amount, through the food chain enrichment can pose a threat to human health

The correlation between organic pesticides and heavy metals in soil and maize is analyzed in figures 1-4. The results showed that heavy metals As, Pb, Cr and DDT were significantly correlated in soil and maize, with correlation coefficients of 0.924, 0.852, 0.90 and 0.843, respectively, this indicated that As, Pb, Cr and DDT in maize were closely related to the content of soil.

Table 8. Residues of Organic Pesticides and Heavy Metals in Maize($\text{mg}\cdot\text{kg}^{-1}$)

Location	Hg	As	Pb	Cd	Cr	Cu	BHC	DDT
Hannan	-	0.66	3.21	0.01	4.7	1.8	0.018	0.027
Dongxihu	0.01	0.56	1.78	0.01	3.8	2.6	0.011	0.014
Caidian	0.01	0.62	2.53	0.01	3.4	2.1	0.010	0.021

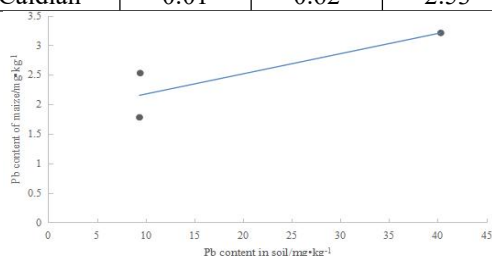


Figure 1. Correlation of Pb Contents between Soil and Maize

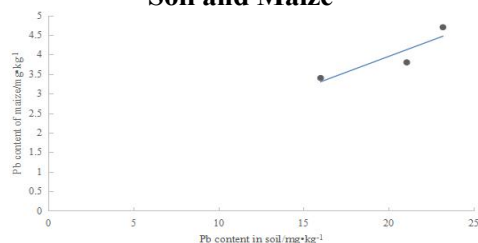


Figure 2. Correlation of Cr Contents between Soil and Maize

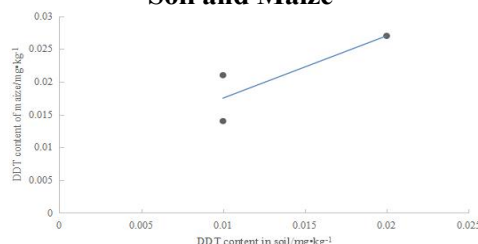


Figure 3. Correlation of DDT Contents between Soil and Maize

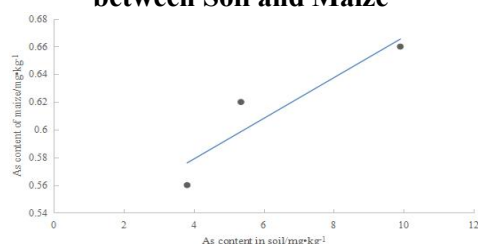


Figure 4. Correlation of As Contents between Soil and Maize

Although the soil and corn quality of the three corn planting bases in Wuhan have been affected by environmental and human factors to a certain extent, the overall situation is still under control. In order to maintain and improve the quality of soil and crops, it is recommended to further strengthen soil management and environmental protection measures, such as balanced fertilization, reducing the use of heavy metals and organic pesticides. At the same time, it is also necessary to continue to monitor and assess the quality of soil and crops to identify and resolve problems in a timely manner.

4. Conclusions

This research undertook a comprehensive analysis of soil characteristics and maize grain quality across three agricultural sites in Wuhan. Soil samples from all locations exhibited mildly acidic conditions and abundant organic matter. In contrast, the distribution of primary macronutrients namely nitrogen, phosphorus, and potassium showed marked heterogeneity among sites, while concentrations of key micronutrients remained consistently low. Consequently, the overall soil fertility status was assessed as moderate. Regarding contamination, the integrated pollution index for heavy metals including cadmium, lead, arsenic, copper, and mercury fell within acceptable limits, fully complying with China's Soil Environmental Quality Standard for Agricultural Land (GB 15618-2018). Likewise, residue levels of both heavy metals and synthetic organic pesticides detected in maize kernels were well below the maximum allowable concentrations specified in

the Green Food Safety Standards (NY/T 391-2021). However, a comparatively higher bioconcentration factor was observed for several organophosphate and organochlorine compounds, indicating enhanced uptake and retention of these substances by maize plants under local cultivation practices.

Acknowledgements

This study was supported by Hubei Agricultural Science and Technology Innovation Center's special fund "2020 key technology research and demonstration project for safe and efficient production of genuine medicinal materials"(NO:2020-620-000-002-04), The 2023 innovation system project of the Wuhan Academy of Agricultural Sciences(XKCX202307).

References

- [1] Zhang O N, Zeng Q P, Tian F, et al. Analysis on the changes of maize sown area and yield in China from 1997 to 2020. *Crop Research*, 2024, 38(4):329-333.
- [2] Zou X, Wang Q F, Wang X S, et al. The spatial patterns of corn-growing region in Hubei province. *Hubei Agricultural Sciences*, 2016, 55(14):3601-3604+3612.
- [3] Xu J M, Liu X M. Frontier trends and development strategies of soil quality and food safety in the 14th five-year plan. *Acta Pedologica Sinica*, 2020, 57(5):1143-1154.
- [4] Zhao X Q, Pan X Z, Ma H Y, et al. Scientific issues and strategies of acid soil use in China. *Acta Pedologica Sinica*, 2023, 60(5):1248-1263.
- [5] Zhang F Y, Liu B S, Lü H Y, et al. Status and countermeasures of secondary salinization in China's facility soil. *Soils and Crops*, 2026, 15(3):437-447.
- [6] Li L M. Research on impact and remediation of agricultural soil environmental pollution food security. *Environmental Science and Management*, 2025, 50(6):177-182.
- [7] Wang Y M, Yuan Y Z, Wang Z C. Long-term effects of biochar coupled with chemical fertilizer Reduction on the safe production of sweet corn in heavy metal contaminated soils. *Ecology and Environmental Sciences*, 2025, 34(12):1962-1973.
- [8] Tian J, Yu J, Zhang K L, et al. Determination of available phosphorus in soil by flow injection analyzer. *Chinese Journal of Inorganic Analytical Chemistry*, 2026, 16(7):1334-1343.
- [9] Chen B, Liu L W, Shen Y, et al. Evaluation of soil fertility quality and analysis of its variation characteristics in Xuanwei Tobacco Area. *Soils*, 2026, 58(2):486-493.
- [10] Zhai K. Soil quality assessment of Hubei Fritiuarria planting base. *Journal of Hubei University for Nationalities (Natural Science Edition)*, 2011, 29(2):235-236.