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# Evaluation on abundance or deficiency of available trace elements in soil of middle area in China and the effect of applying trace element fertilizer

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**Abstract** — The authors selected the west part of Xinxiang City, Henan Province in the north China plain as a typical region and carried out assessments of the abundance or deficiency of the trace elements (B, Mn, Mo, Zn, Cu, Fe) in soil. It can be seen from results that more than 80% of the farmland is deficiency of zinc (<1.0ppm), 40% of molybdenum (0.15ppm), 38% of boron (0.5ppm), 29% of manganese (100ppm) and 13% of iron (7.0ppm) and that the content of available trace elements in soil are related to the topography closely. Next the proper application of trace elements on grain crops is presented.

**Keywords:** evaluation; available trace element; soil type; topography.

## 1 Introduction

Chinese agriculture has a long history, but the yield of crops was very low in the past, for example, the wheat was only 1500 kg/ha. One of the major factor was that the soil fertility only can keep its nutrition balance in a low level by the way of using organic fertilizer and growing leguminous or green manure crops.

In recent decades a great amount of chemical fertilizer (N, P and K) have been used in crop production, so as to make the crop yield increase very quickly.

With usage of chemical fertilizer and other measures, the national grain output has been increased from 113.2 billion kilograms in 1949 to 407.3 billion kilograms in 1989, over 3 times higher. However only in a few area fertilizers of trace elements have been used in agriculture production, so that in a large agricultural area the soil trace elements are obvious deficiency. It is also because of reduction in application of organic fertilizer, the contents of trace elements in soil which are essential for plant growth were reduced and led to occurrence of some plant disease, such as albino plant to maize, heart rot of beet, little leaf disease of apple and peach and yellow leaf disease of several kinds of trees and the yield of some crops decreased. In such a case the evaluation on abundance or deficiency of available trace elements in soil and applying the fertilizer of trace elements to soil is necessary for increasing the yield of crops, vegetables, fruit trees and other economic plants.

## 2 Experimental

### 2.1 Evaluation on abundance or deficiency of trace elements in soils of four counties, western Xinxiang City, Henan Province

Xinxiang City is one of the typical agricultural area in Huang-Huai-Hai Plain, so we look on it as a representative region in this plain to conduct the study on soil trace elements.

The four counties (Weihui, Hui, Xinxiang and Huojia) located on the west of Xinxiang City have 3880 square kilometers. We collected the samples of top soil (0-25cm) in 164 points including 12 profiles of different types of soil and analyzed 6 kinds of main trace elements for plant growth (B, Mn, Zn, Mo, Fe, and Cu). All these trace elements were determined the amount of available form in soil according to the book of "The conventional methods of analysis for soil and agriculture chemistry". The Zn, Cu and Fe in soil were determined after extraction with solution of DTPA (pH 7.30) by atomic absorption spectrophotometry (AAS). The easily reducible manganese was extracted with 1 mol/L $NH_4OAC$ (pH 7.0) alone with hydroquinone, and measured by AAS. Boron was extracted use boiling water and measured by spectrophotometry. The results of this study are as follows.

#### 2.1.1 The evaluation criterion abundance or deficiency of available trace elements in soil (Table 1)

**Table 1 The evaluation criterion for abundance or deficiency of available trace elements in soils**

| Elements | Grading | | | | | Deficient value |
|---|---|---|---|---|---|---|
| | Very low | Low | Medium | High | Very high | |
| B | 0.25 | 0.25-0.5 | 0.50-1.0 | 1.1-2.0 | 2.0 | 0.50 |
| Mn | 50 | 50-100 | 100-200 | 200-300 | 300 | 100 |
| Zn | 0.50 | 0.50-1.0 | 1.0-2.0 | 2.0-5.0 | 5.0 | 1.0 |
| Mo | 0.10 | 0.10-0.15 | 0.15-0.2 | 0.2-0.3 | 0.30 | 0.15 |
| Fe | 5.0 | 5.0-7.0 | 7.0-10.0 | 10.0-15.0 | 15.0 | 7.0 |
| Cu | 0.10 | 0.10-0.20 | 0.20-1.0 | 1.0-1.8 | 1.8 | 0.20 |

Notes: The evaluation criterion for Mn with easily reducible form.

2.1.2 The results of evaluation on soil of whole region

According to the evaluation criterion in Table 1, the trace element content of each soil sample are divided into the different classifications and the soil sample number in each classification are computed to be percentages in Table 2.

**Table 2 Comparison of abundance or deficiency on available trace element in soils of four counties in the western Xinxiang City**

| Element | Collecting sites of soil | Percentage of sites in different levels of trace elements in soil | | | | | |
|---|---|---|---|---|---|---|---|
| | | Very low | Low | Medium | High | Very high | Deficient, % |
| Zn | 163 | 71.4 | 13.1 | 10.4 | 5.3 | 0 | 84.5 |
| B | 164 | 4.7 | 33.8 | 56.0 | 5.5 | 0 | 38.5 |
| Mn | 164 | 5.2 | 24.0 | 66.1 | 4.7 | 0 | 29.2 |
| Mo | 164 | 5.3 | 36.6 | 20.1 | 35.1 | 2.9 | 41.9 |
| Fe | 164 | 2.5 | 10.2 | 30.9 | 40.8 | 15.6 | 12.7 |
| Cu | 164 | 0 | 0 | 28.0 | 56.6 | 15.4 | 0 |

From the last vertical line in Table 2, it can be seen that 84.5% of the total farmland is deficiency of zinc, which means its under the low contents or low plus very low, 41.9% is deficiency of molybdenum, 38.5% is deficiency of boron, 29.2% is deficiency of manganese, 12.7% is deficiency of iron and there is no deficiency of copper.

2.1.3 The results of evaluation of the different types of soil

There are 7 different types of soil distributed in whole region. They are drab soil, alluvial drab soil, yellow drab soil, leaching drab soil, paddy soil, saline alluvial soil and sand soil.

The comparison of each trace elements content in different types of soil are as follows:

Zinc: It can been seen from Table 3 that the paddy soil, saline alluvial soil and alluvial sand soil are all one hundred percentage dificiency of zinc. Drab soil, leaching drab soil and yellow alluvial soil are over 80% deficiency of Zn. Only alluvial drab soil is 72.7% deficiency of Zn. This comparison results explained clearly that the deficiency of Zn is a common problem in the farmland of this region.

Boron: It can be shown from Table 4 that in order of the percentage of deficiency of boron is alluvial sand soil and paddy soil (100%), drab soil, leaching drab soil and sand soil (67% - 83%), alluvial drab soil (46%), yellow alluvial soil (25.7%), saline alluvial soil.

**Table 3 Comparison of available zinc content (ppm) in different soils**

| Soil type | Number of soil sample | Range of content | Average of content | *S.D.* | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 14 | 0.20 – 1.12 | 0.51 | 0.400 | 85.7 |
| Leaching drab soil | 7 | 0.14 – 1.35 | 0.48 | 0.404 | 85.7 |
| Alluvial drab soil | 44 | 0.04 – 2.88 | 0.73 | 0.774 | 72.7 |
| Yellow alluvial soil | 71 | 0.002 – 2.74 | 0.51 | 0.536 | 88.7 |
| Saline alluvial soil | 7 | 0.002 – 0.41 | 0.12 | 0.144 | 100.0 |
| Paddy soil | 3 | 0.09 – 0.42 | 0.29 | – | 100.0 |
| Alluvial sand soil | 3 | 0.002 – 0.07 | 0.03 | – | 100.0 |

Notes: the percentage accounting for sample collecting sites

**Table 4 Comparison of availabe boron content (ppm) in the different soils**

| Soil type | Number of soil sample | Range of content | Average of content | *S.D.* | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 15 | 0.25 – 0.98 | 0.46 | 0.211 | 66.7 |
| Leaching drab soil | 6 | 0.30 – 0.53 | 0.40 | 0.091 | 83.3 |
| Alluvial drab soil | 22 | 0.20 – 0.90 | 0.53 | 0.170 | 46.2 |
| Yellow alluvial soil | 69 | 0.20 – 1.85 | 0.69 | 0.291 | 25.7 |
| Saline alluvial soil | 6 | 0.64 – 1.64 | 0.99 | 0.414 | 0.0 |
| Paddy soil | 3 | 0.26 – 0.41 | 0.35 | – | 100.0 |
| Alluvial sand soil | 3 | 0.002 – 0.07 | 0.03 | – | 100.0 |

[1] The same as in Table 3

**Table 5 Comparison of available manganese content (ppm) in the different soils**

| Soil type | Number of soil sample | Range of content | Average of content | *S.D.* | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 15 | 134 – 256 | 165.6 | 28.574 | 0.0 |
| Leaching drab soil | 7 | 169 – 216 | 197.8 | 16.654 | 0.0 |
| Alluvial drab soil | 44 | 62.7 – 199 | 125.2 | 28.884 | 18.0 |
| Yellow alluvial soil | 73 | 34.9 – 204 | 111.9 | 45.036 | 45.2 |
| Saline alluvial soil | 7 | 72.8 – 161 | 89.5 | 33.803 | 57.1 |
| Paddy soil | 3 | 37.7 – 55.9 | 46.8 | – | 100.0 |
| Alluvial sand soil | 3 | 34.9 – 63.0 | 47.1 | – | 100.0 |

Manganese: Table 5 shows in the order of the percentage of deficiency of Mn is paddy and alluvial sand soil (100%), yellow and saline alluvial soil (45.2%–57.1%), alluvial drab soil (18%), drab soil and leaching drab soil (0%).

Molybdenum: Table 6 shows in the order of the percentage of the deficiency is leaching drab soil and alluvial sand soil (100%), saline alluvial soil and paddy soil (83%), alluvial drab soil and drab soil (46% − 47%), yellow alluvial soil (33%).

As mentioned above, Zn, B, Mn and Mo are deficiency in the farmland of the four counties, Western Xinxiang City (Fig. 1 − 4).

Besides, iorn is deficient only in alluvial sand soil, drab soil, alluvial drab soil and saline alluvial soil (12.7%). The available copper is not deficient in all kinds of soil (Fig. 5, 6; Table 7, 8).

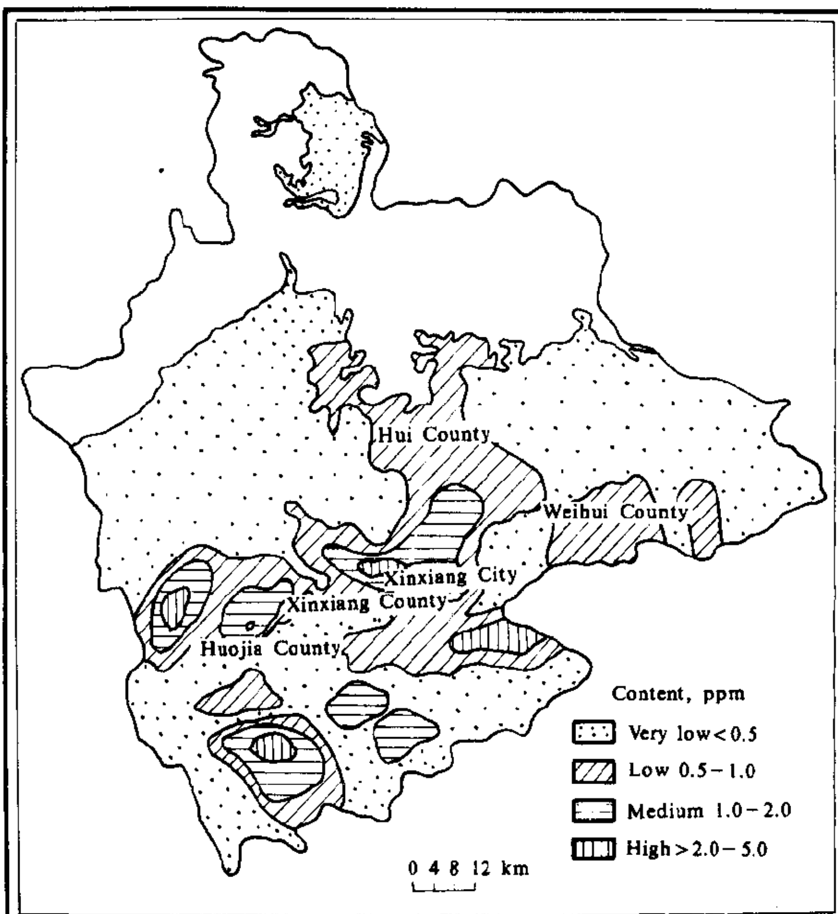


Fig. 1 Distribution of available Zn in soils of four counties, west of Xingxiang City

**Table 6 Comparison of available molybdenum content (ppm) in the different soils**

| Soil type | Number of soil sample | Range of content | Average of content | *S.D.* | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 15 | 0.09–0.29 | 0.18 | 0.072 | 46.7 |
| Leaching drab soil | 7 | 0.09–0.14 | 0.11 | 0.021 | 100.0 |
| Alluvial drab soil | 43 | 0.07–0.62 | 0.19 | 0.076 | 45.8 |
| Yellow alluvial soil | 70 | 0.06–0.74 | 0.19 | 0.060 | 32.9 |
| Saline alluvial soil | 6 | 0.12–0.23 | 0.15 | 0.043 | 83.3 |
| Paddy soil | 3 | 0.14–0.20 | 0.17 | – | 83.3 |
| Alluvial sand soil | 3 | 0.10–0.13 | 0.12 | – | 100.0 |

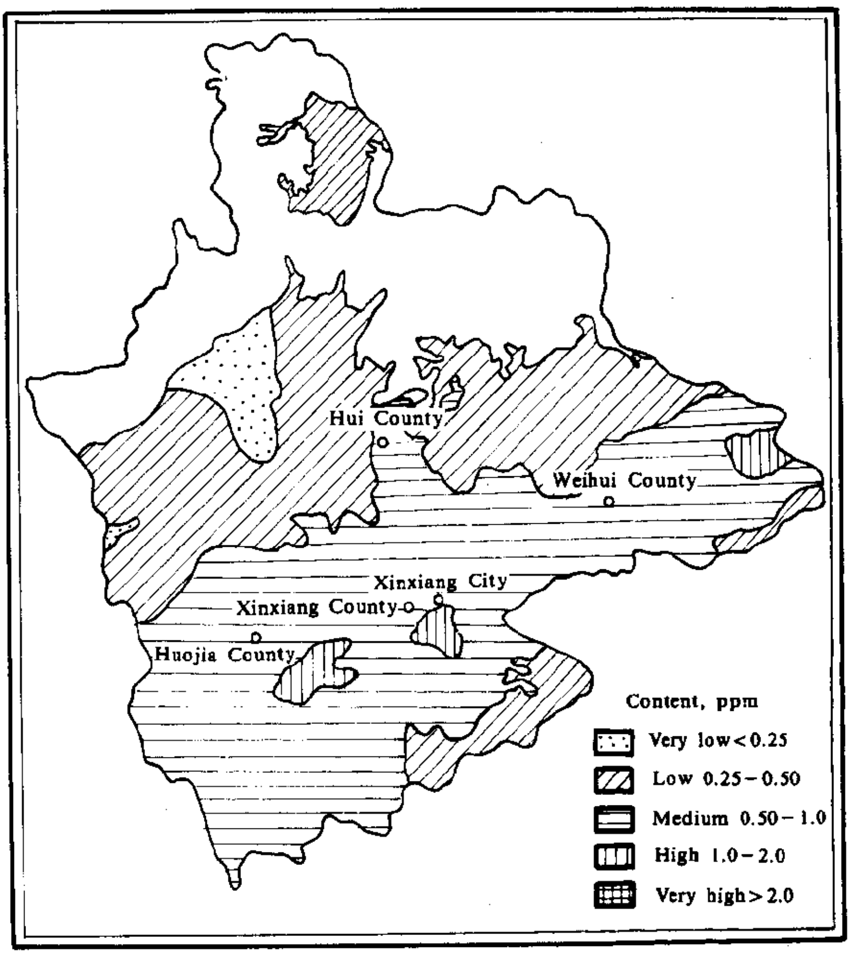


Fig. 2 Distribution of available B in soils of four counties, west of Xinxiang City

**Table 7 Comparison of available iron content (ppm) in the different soils**

| Soil type | Number of soil sample | Range of content | Average of content | *S.D.* | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 15 | 5.41 – 12.4 | 8.70 | 2.287 | 26.7 |
| Leaching drab soil | 6 | 13.03 – 15.5 | 14.47 | 0.869 | 0.0 |
| Alluvial drab soil | 43 | 5.15 – 15.9 | 9.63 | 2.282 | 30.8 |
| Yellow alluvial soil | 70 | 3.97 – 52.8 | 13.35 | 8.465 | 4.3 |
| Saline alluvial soil | 6 | 3.43 – 10.1 | 6.38 | 3.042 | 16.7 |
| Paddy soil | 3 | 20.30 – 44.9 | 36.03 | – | 0.0 |
| Alluvial sand soil | 3 | 5.63 – 8.22 | 7.28 | – | 33.3 |

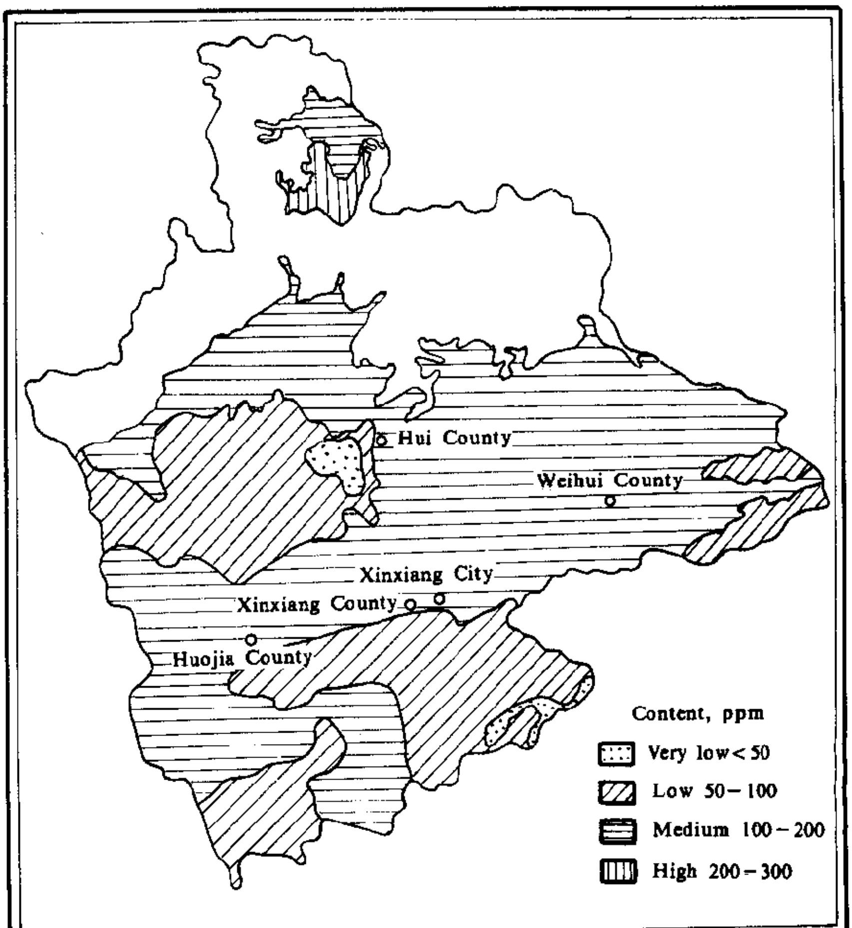


Fig. 3 Distribution of available Mn in soils of four counties, west of Xinxiang City

**Table 8 Comparison of available copper content (ppm) in the different soils**

| Soil type | Number of soil sample | Range of content | Average of content | S.D. | Deficient, % |
|---|---|---|---|---|---|
| Drab soil | 13 | 0.67 – 2.00 | 1.09 | 0.391 | 0.0 |
| Leaching drab soil | 77 | 0.99 – 1.48 | 1.29 | 0.183 | 0.0 |
| Alluvial drab soil | 43 | 0.41 – 2.84 | 1.31 | 0.461 | 0.0 |
| Yellow alluvial soil | 72 | 0.31 – 3.88 | 1.46 | 0.646 | 0.0 |
| Saline alluvial soil | 7 | 0.52 – 0.95 | 0.71 | 0.179 | 0.0 |
| Paddy soil | 3 | 2.59 – 3.29 | 2.99 | – | 0.0 |
| Alluvial sand soil | 3 | 0.21 – 0.62 | 0.41 | – | 0.0 |

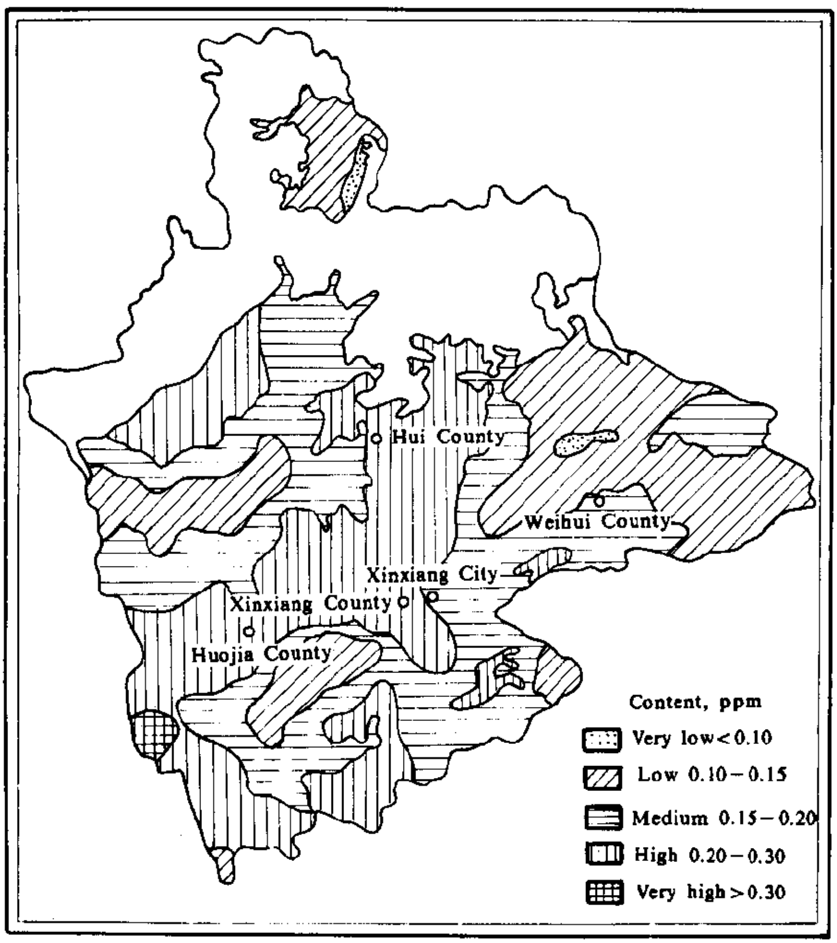


Fig. 4 Distribution of available Mo in soils of four counties, west of Xinxiang City

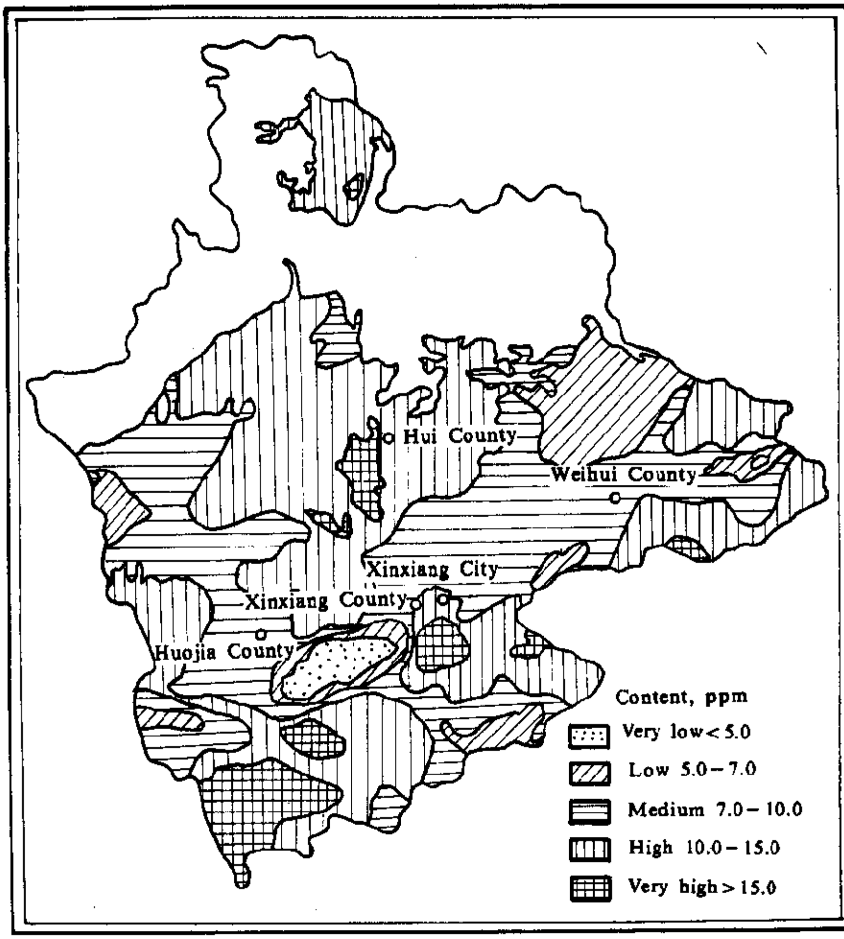


Fig. 5 Distribution of available Fe in soils of four counties, west of Xinxiang City

2.1.4 The trace elements contents related to the topography and landform

To understand the relation between the content of available trace elements with topography and landform, Weihui County with a complex topography was selected to map the distribution of different trace elements.

The topography of Weihui County is from the mountain area in northeast to a slope in the center and to the plain in the south. It can be seen from Fig. 2 that the content of available boron is on the increase from the mountain area to the plain. On the contrary the content of available manganese is on the decrease from the mountain area to the plain. The third situation is that zinc is low in all areas. Finally, there is no any regularity of the distribution of other trace elements.

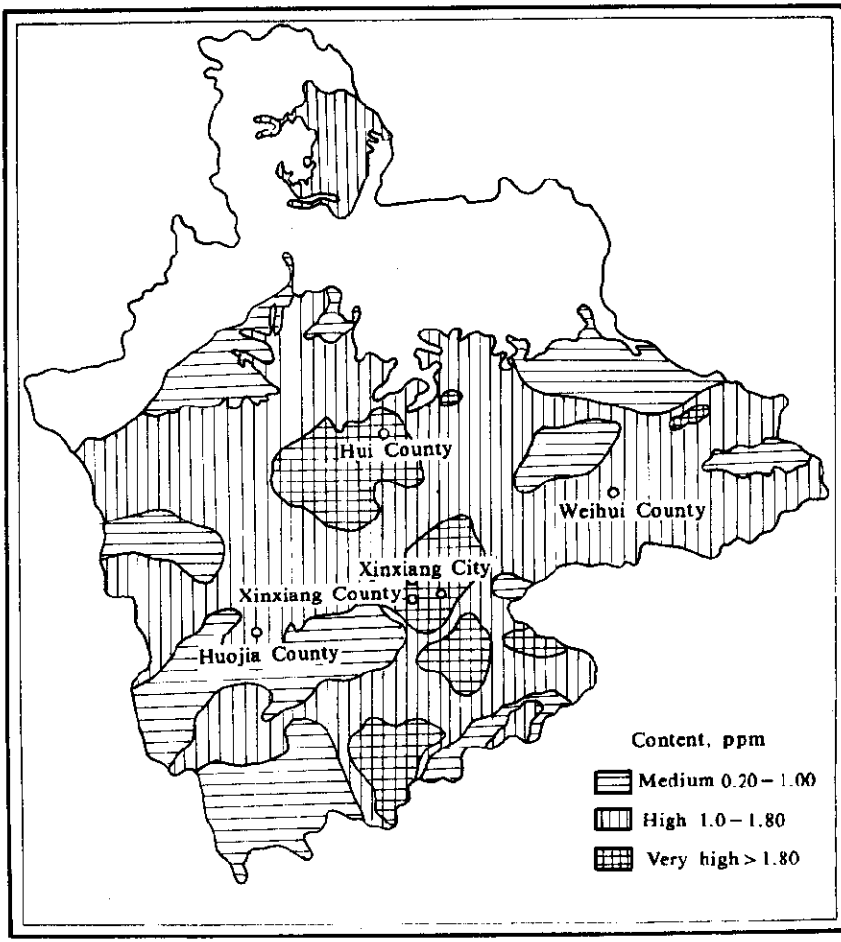


Fig. 6 Distribution of available Cu in soils of four counties, west of Xinxiang City

2.2 The response in seed yield of crops to soil applications of trace elements fertilizer

2.2.1 The amount of applying trace elements to soil

On the basis of the experimental results, the amount of trace elements of applying to soil was decided in Table 9.

2.2.2 The response in seed yield of wheat to soil applications trace elements fertilizer (Table 10, 11)

**Table 9 The amount of applying trace elements to soil**

| Trace elements | Chemical compounds | Applying amounts[1], kg/mu, 1ha=15mu |
|---|---|---|
| Zn | $ZnSO_4 \cdot 7H_2O$ | 1.0 |
| B | $H_3BO_3$ | 0.6 |
| Mn | $MnSO_4$ | 0.75 |
| Mo | $(NH_4)_2MoO_4$ | 0.25 |

[1] Amount of chemical compounds

**Table 10 The response in grain yield of wheat to soil applications of trace elements fertilizer**

| Experimental location and soil type | Treatment | Height of plant, | | Tillerings, | | Weight of grains, | Increase over control, |
|---|---|---|---|---|---|---|---|
| | | cm | % | Number | % | kg/mu[1] | % |
| Suburb of Weihui City (Alluvial soil) | Zn | 80.5 | 115.5 | 4.8 | 114.2 | 390.7 | 22.2 |
| | B | 79.0 | 111.2 | 5.0 | 119.0 | 401.3 | 25.5 |
| | Mn | 82.6 | 116.0 | 5.0 | 119.0 | 390.3 | 22.0 |
| | CK | 71.2 | 110.0 | 4.2 | 100.0 | 319.7 | – |
| Suburb of Weihui City (Alluvial sand soil) | Zn | 85.2 | 101.4 | 4.9 | 122.5 | 429.4 | 15.9 |
| | B | 87.1 | 103.8 | 4.4 | 110.0 | 398.9 | 7.7 |
| | Mn | 85.1 | 101.3 | 4.6 | 115.0 | 407.2 | 9.9 |
| | CK | 84.0 | 100.0 | 4.0 | 100.0 | 370.5 | – |

[1] 1 ha = 15mu

**Table 11 The response in seed yield of peanut to soil application of trace elements**

| Treatment | Number of fruit, a plant | Weight of seeds/kg, per/mu[1] | Increase over control, % |
|---|---|---|---|
| Zn | 15.8 | 165 | 9.2 |
| Mo | 16.7 | 168 | 11.3 |
| CK | 14.3 | 151 | – |

[1] 1 ha = 15mu

It can be seen that the yield of wheat and peanut after applying the trace elements fertilizer was increased obviously, so we believe that the application of trace elements will become a very important measure of crop production in Huang-Huai-Hai plain in not far future.

## 3 Conclusion

It was found from this study that the contents of available trace elements Zn, B, Mn, Mo and Fe in many kinds of soil in Huang-Huai-Hai Plain are deficient. To meet the nutritional requirement of crops, some research works should be continued, such as compound fertilizers composed of different trace elements which crops are needed, adsorption, leaching and available period of different trace elements applied to soil as well as their cycling in pedosphere.

On the basis of the other researches we have done, selenium and cobalt are also deficient in some soil, so the survey and analysis for them should be carried out at an early date.

In addition, the distribution of trace elements in the different profiles and the relationship between the trace elements with nitrogen, phosphorus, potassium and organic matter has been also carried out and will be reported in other paper.

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