Effects of Overwintering Green Manure Brassica napus L. on Chemical Properties and Heavy Metal Content of Paddy Soil

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Abstract. In order to explore the response mechanism of heavy metal content in Oryza sativa L. fields under winter green manure. In this study, through field experiments, the changes of soil chemical properties and heavy metal content in Brassica napus L. and Oryza sativa L. at different growth stages were analyzed. The results are as follows: the pH value in Brassica napus L. harvest stage is higher than that before sowing, while the pH value in Oryza sativa L. harvest stage is lower than that before sowing. Eh of Brassica napus L. soil is positive during the whole growth period, showing a fluctuating upward trend. Eh of soil decreased to negative value during the whole growth period of Oryza sativa L. The contents of As, Hg, Pb, Cd and Cr in the soil decreased gradually in the whole growth period of Brassica napus L., and decreased to the lowest level in the harvest period. During the whole growth period of Oryza sativa L., the content of Hg and Cd decreased, while the content of Pb and Cr increased in the harvest period compared with before sowing. Therefore, planting green manure Brassica napus L. in winter is beneficial to alleviate heavy metal pollution in soil.

Keywords: Oryza Sativa L., Brassica Napus L., Soil Chemical Properties, Heavy Metals In Soil

Introduction

The content of heavy metals in soil is related to food safety and human and animal health. As an important evaluation index of soil quality, people are paying more and more attention to it[1]. Fertilization is an indispensable measure to increase production in agricultural production[2]. Different fertilization measures, such as returning straw to the field, applying a large amount of organic fertilizer
or organic-inorganic fertilizer mixture, can significantly affect the total or effective content of heavy metal elements in soil [3-5]. Different forms of heavy metals lead to great differences in their physiological activities and toxicity, of which the water-soluble state and exchange state have the largest activity and toxicity, while the residual state has the smallest activity and toxicity, and the other binding states have the middle activity and toxicity [6]. The application of green manure to the soil not only increases the nutrient components required for plant growth such as nitrogen fertilizer, phosphate fertilizer and organic matter in the soil, but also changes the pH value of the soil, redox potential and the life activities of microorganisms, etc. These factors will directly or indirectly affect the existing forms of heavy metals in the soil, thus promoting or inhibiting the absorption of heavy metals by plants.

Scholars at home and abroad have made progress in researches on the effects of green manure on crop yield and quality, on soil nutrients and fertility, and on changes in microbial activity and heavy metal content in soil. Kaifang Zhou and others’ study of two treatments of green manure with and without turning pressure (control), found that compared with the physical and chemical properties of the topsoil before the test, the organic matter, alkali-hydrolyzable nitrogen, available phosphorus and available potassium of the soil increased by 0.07%, 1.9 mg/kg, 4.7 mg/kg and 3.1 mg/kg respectively after the green manure was turned over and pressed. The pH value of the soil changes from 5.5 to 6.0, the bulk density of the soil decreases by 0.05g/cm³, and the porosity increases by 1.9%[7]. Some experimental results show that turning over and pressing green manure can effectively reduce the bulk density and pH value of the soil, improve the organic matter of the soil, and at the same time can promote a large increase in the number of microorganisms in the soil [8]. Shuangshuang Du studied the effects of adding *Oryza sativa* L. straw and *Astragalus sinicus* L. on the availability and morphological changes of arsenic and cadmium in acidic soil through soil simulation culture experiments [9]. *Astragalus sinicus* L. and *Oryza sativa* L. straw alone and in combination can reduce the availability of arsenic in acidic soil. Compared with the control, the addition of *Oryza sativa* L. straw and/or *Astragalus sinicus* L. significantly increased the effective tillering number and yield of *Oryza sativa* L. and reduced the toxicity of arsenic and cadmium to *Oryza sativa* L. Returning *Oryza sativa* L. straw to field, turning over green manure (*Astragalus sinicus*) and their combination can reduce the availability of cadmium in acidic soil and alleviate the effects of cadmium on *Oryza sativa* L. growth, yield and food safety. In recent years, there have been many studies on the effects of nitrogen application and winter green manure on soil physical and chemical properties and biological properties, but there are few studies on the status of heavy metals in paddy soil. Therefore, this study measured the changes of soil basic chemical properties and heavy metals content by planting *Brassica napus* L., and studied the effects of planting green manure on the physical and chemical properties and heavy metals content of paddy soil, providing theoretical basis for the protection of agricultural ecological environment and even the sustainable development of social economy.

**Materials and Methods**

**Test Material**
*Brassica napus* L. green manure crops were used in the experiment.

**Test Method**
The *Oryza sativa* L.-*Brassica napus* L. rotation system is designed according to the local traditional farming method, and *Brassica napus* L. is irrigated and soaked in the field after being turned over for transplanting. *Brassica napus* L. is sown in late September and rolled over in April of the following year. *Oryza sativa* L. is transplanted in the first ten days of May and harvested in the second ten days of October. *Oryza sativa* L. management is carried out in accordance with common fields. Samples of topsoil (0-20cm) in the root area were collected before *Brassica napus* L. sowing and at three growth stages (seedling stage, bolting stage, flowering stage, harvest stage), before *Oryza sativa* L. sowing and at four growth stages (seedling stage, tillering stage, grouting stage, harvest stage). Five sampling
points were set for each sampling unit. The sampling points were as far away from ridges and roads as possible. Each soil sample was marked with sample number, sampling time, place, sampling person, etc. In *Oryza sativa* L. season, stainless steel earth drill was used for sampling, 20-40cm soil column was collected, and the topsoil contacting with metal materials was stripped. When *Oryza sativa* L. and green manure samples are collected, the plant sampling points correspond to the soil sampling points one by one. In each soil sampling unit, plant samples are taken according to the soil sampling position, the sampling amount is the same as the soil sampling amount, but at least one individual is taken indoors, and then each organ is treated separately. The samples are washed with tap water first, then with de-enzyming treatment, dried, ground and sealed in polyethylene plastic bags.

According to the national and industry standards, and referring to the "Soil Agrochemical Analysis Method" and the Agricultural Industry Standard Test of the People's Republic of China (NY/T391-2000), soil chemical indexes are determined: (1) Soil pH is determined by potentiometric method (soil-liquid ratio: 1: 2.5); (2) Soil Eh was directly determined by platinum electrode. (3) Soil organic matter was determined by potassium dichromate external heating method. (4) The total amount of heavy metals in soil was digested by HNO3-HF microwave, and the total amount of heavy metals in plants was digested by HNO3-H2O2 microwave, all of which were determined by ICP-OES(prodigy xp).

**Results and Analysis**

**Changes of Soil Chemical Properties during *Oryza sativa* L.-*Brassica napus* L. Planting**

| Indicators | *Brassica napus* L. sampling period | *Oryza sativa* L. sampling period |
|------------|------------------------------------|----------------------------------|
|            | Befor e Sowing | Seedling Stage | Bolting Period | Florescense | Harvest | Befor e Sowing | Seedling Stage | Tillering Stage | Postulation Period | Harvest |
| pH         | 8.26         | 8.36         | 8.30         | 8.33        | 8.35        | 8.31         | 8.15         | 8.07         | 8.17         | 8.12     |

From Table 1, it can be seen that during the growth of *Brassica napus* L., the change of soil pH value is not obvious, and the fluctuation range is relatively narrow, ranging from 8.26 to 8.36. From before sowing to seedling stage, pH value showed an increasing trend, decreased gradually at bolting stage, and finally rose again at harvest stage. The range of soil pH value during *Oryza sativa* L. growth is 8.07-8.31. The pH value gradually decreases from before sowing to tillering stage, then increases slightly in filling stage and decreases to 8.12 in harvest stage.

**Table 2. Changes of Soil Eh during *Oryza sativa* L.-*Brassica napus* L. Planting**

| Indicators | *Brassica napus* L. sampling period | *Oryza sativa* L. sampling period |
|------------|------------------------------------|----------------------------------|
|            | Befor e Sowing | Seedling Stage | Bolting Period | Florescenc e | Harvest | Befor e Sowing | Seedling Stage | Tillering Stage | Pustulation Period | Harvest |
| Eh(mV)     | 2.0         | 25.6         | 183.5         | 45.3        | 117.4       | -425.0      | -258.2      | -195.2         | -199.2       | -203.9   |

During the whole growth period of *Brassica napus* L., the Eh value of soil showed a fluctuating upward trend (table 2), reaching the maximum value of 183.5mV during bolting period. Although the flowering period decreased, it maintained a rising trend during harvest period. During the whole growth period of *Oryza sativa* L., the Eh value of soil increased first and then decreased slightly and then be stable, from -425.0mV before sowing to -203.9mV during harvest.
Table 3. Changes of Soil organic matter during *Oryza sativa* L.-*Brassica napus* L. Planting

| Indicators | *Brassica napus* L. sampling period | *Oryza sativa* L. sampling period |
|------------|------------------------------------|----------------------------------|
|            | Before Sowing | Seedling Stage | Bolting Period | Florescence | Harvest | Before Sowing | Seedling Stage | Tilling Period | Harvest |
| Organic Content (g/kg) | 57.1 | 51.6 | 54.7 | 56.8 | 54.6 | 56.3 | 54.8 | 55.7 | 55.2 |

From Table 3, it can be seen that in the whole growth period of *Brassica napus* L., the change of soil organic matter first decreases and then increases. The change range of organic matter is 51.6-56.8 g/kg, and the organic matter content at seedling stage is the lowest, 51.6 g/kg. Before sowing, the organic matter content is the highest, reaching 57.1 g/kg. During the whole growth period of *Oryza sativa* L., the change range of soil organic matter is relatively small, ranging from 54.8 g/kg to 56.3 g/kg, with the lowest organic matter content at seedling stage and the highest organic matter content before sowing.

Changes of Heavy Metals in Soil during *Oryza sativa* L.-*Brassica napus* L. Planting

Table 4. Changes of heavy metal content in soil *Oryza sativa* L.-*Brassica napus* L. Planting

| Indicators (mg/g) | *Brassica napus* L. sampling period | *Oryza sativa* L. sampling period |
|-------------------|------------------------------------|----------------------------------|
|                   | Before Sowing | Seedling Stage | Bolting Period | Florescence | Harvest | Before Sowing | Seedling Stage | Tilling Stage | Harvest |
| As                | 12.0 | 12.0 | 11.3 | 10.6 | 9.7 | 9.8 | 9.6 | 9.9 | 10.0 |
| Hg                | 0.065 | 0.062 | 0.058 | 0.051 | 0.048 | 0.049 | 0.04 | 0.042 | 0.048 |
| Pb                | 37.0 | 37.1 | 35.8 | 34.3 | 33.2 | 33.8 | 33.0 | 33.5 | 34.4 |
| Cd                | 0.26 | 0.26 | 0.24 | 0.24 | 0.22 | 0.28 | 0.26 | 0.25 | 0.25 |
| Cr                | 82.0 | 80.0 | 78.0 | 74.0 | 68.0 | 73.0 | 75.0 | 78.0 | 80.0 |

As can be seen from table 4, the content of As in the soil shows a decreasing trend during *Brassica napus* L. growth, with the highest content of 12.0 mg/kg before sowing and at seedling stage and 9.7mg/kg at harvest. During the whole growth period of *Oryza sativa* L., the content of As in the soil at the filling stage was the highest 10.0 mg/kg, while the content at the seedling stage was the lowest 9.6mg/kg. The content of Hg in the soil showed a decreasing trend during *Brassica napus* L. growth, with the highest content before sowing at 0.065 mg/kg and the lowest content at harvest at 0.048mg/kg. During the whole growth period of *Oryza sativa* L., the content of As in soil decreased first and then increased. Before sowing, the content of As in soil was 0.049 mg/kg at the highest and 0.04mg/kg at the lowest filling stage. The content of Pb in the soil increased first and then decreased during *Brassica napus* L. growth. The highest content was 37.1 mg/kg at seedling stage and decreased to 33.2mg/kg at harvest. During the whole growth period of *Oryza sativa* L., the content of Pb in soil decreased first and then increased and then decreased. The highest content of Pb in soil was 34.4 mg/kg during filling period, and the lowest content in seedling period was 33.0mg/kg. The content of Cd in the soil showed a decreasing trend during the growth period of *Brassica napus* L.. The highest content was 0.26 mg/kg before sowing and at seedling stage, and decreased to 0.22mg/kg at harvest time. During the whole growth period of *Oryza sativa* L., the content of soil Cd decreased gradually, with the highest content of soil Cd being 0.28 mg/kg before sowing and the lowest content being 0.20mg/kg during harvest. The content of Cr in the soil showed a decreasing trend during *Brassica napus* L. growth, with the highest content of 82mg/kg before sowing and 68mg/kg at harvest. During
the whole growth period of *Oryza sativa L.*, the content of Cr in soil increased first and then decreased and then increased. The highest content of Cr in soil was 80 mg/kg in harvest period and the lowest content was 73 mg/kg before sowing.

**Discussion and Conclusion**

Soil pH is affected by many factors. Climate, irrigation, microorganisms and so on all affect soil pH. This study found that the change rule of soil pH is not obvious during the whole growth period of *Brassica napus L.* and *Oryza sativa L.*. During the whole growth period of *Brassica napus L.*, the soil is in a moderate reduction state, and the soil Eh is positive. During the whole growth period of *Oryza sativa L.*, waterlogged soil has poor aeration and is in a state of intensity reduction, and soil Eh is reduced to a negative value. Danmei Zhu and others’ research results on Eh values of soils with different acid and alkali properties in southern China also show that Eh values will decrease after long-term flooding [10]. The change of soil Eh in this paper is basically the same as that of *Oryza sativa L.* field soil Eh measured by Wang Ming and others continuously during irrigation flooding and drying: Eh decreased during flooding and increased during drying [11]. Decomposition of *Brassica napus L.* residues can increase the content of soil organic matter, which is relatively high in *Brassica napus L.* flowering stage and *Oryza sativa L.* filling stage.

In the *Oryza sativa L.*-*Brassica napus L.* rotation process, the total change of heavy metals in soil, which was originally controlled by parent materials, is caused by a variety of factors. This study found that planting *Brassica napus L.* green manure can reduce the contents of As, Hg, Pb, Cd and Cr in the soil. During the growth period of *Oryza sativa L.*, the contents of Hg and Cd decreased, while the contents of Pb and Cr increased compared with before sowing. Planting *Brassica napus L.* in paddy fields can reduce the content of some heavy metals, and further research is needed on the content changes of soil heavy metals in different forms by planting green manure *Brassica napus L.*.

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