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Copper and Zn uptake by radish and pakchoi as affected by application of livestock and poultry manures

Dong-Mei Zhou *, Xiu-Zhen Hao, Yu-Jun Wang, Yuan-Hua Dong, Long Cang

State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China

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Abstract

Environmental safety of agricultural utilization of livestock and poultry manures from intensive farming is attracting great attention because the manures often contain high concentrations of heavy metals and organic pollutants. Pot experiments, in which a pig manure (PM), a chicken manure (CM) and a commercial organic manure (OM) with different concentrations of Cu and Zn to simulate soil metal accumulation by manure application for different times were utilized in a garden soil at a rate of 2% (W/W), were conducted to study the effect of application of these livestock and poultry manures on growth of radish (*Raphanus sativus* L.) and pakchoi (*Brassica chinensis* L.) as well as their Cu and Zn uptake. The results exhibit that the manures except the PM improved the growth of radish and pakchoi. The difference of biomass among the same manure treatments containing different concentrations of Cu and Zn, however, was insignificant. In addition, application of the livestock and poultry manures significantly increased soil pHs and electric conductivities (EC) compared with the control, which is ascribed that these manures had high pH and contained large amounts of inorganic ions. The available soil Zn concentrations in the PM were higher than that in the CM and OM, and the extractable soil Cu concentrations in the three manures were almost the same after radish growth in the garden soil but were different after pakchoi growth. Zinc and Cu concentrations in the radish and pakchoi tissues increased when the soil Zn and Cu concentrations increased by manures application, but were still within a safe value. An except is the treatment PM4 in which the Zn concentration of the above-ground part of radish was 28.7 $mg\,kg^{-1}$, exceeding the Chinese Food Hygiene Standard of 20 $mg\,kg^{-1}$ based on fresh weight. Good correlation was obtained between the extractable soil Zn (or Cu) concentrations extracted by 1.0 $mol\,l^{-1}$ NH_4NO_3 and the Zn (or Cu) concentrations in radish and pakchoi tissues, which was expected to be effective in forecasting Cu and Zn availability to radish and pakchoi in manure agronomic utilization.
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Keywords: Livestock; Poultry; Manure; Plant uptake; Heavy metal; Radish; Pakchoi

1. Introduction

Excessive application of chemical fertilizer in agricultural soil had caused serious environmental problems in China, including deteriorate soil physical structures, nutrients unbalance of soil, and water eutrophication (Wang et al., 1999). Livestock ad poultry manure can

* Corresponding author. Tel.: +86 25 8688 1180; fax: +86 25 8688 1000.

E-mail address: dmzhou@issas.ac.cn (D.-M. Zhou).

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be an alternative source of fertilizer in organic farming where the use of anthropogenic chemicals is prohibited (Hodeges, 1991; Wong et al., 1999). Meanwhile, it is an economic method to use the manures rather than chemical fertilizer, and also can avoid environmental pollution of manures in areas with high livestock and poultry densities caused by inappropriate disposing. It is well known that manures were rich in N, P and organic matter, and many studies showed that livestock and poultry manures exercised a positive influence on crop production and they also improved soil physical properties (Woodbury, 1992; McConnell et al., 1993; Guisquiani et al., 1995; Tam and Wong, 1995; Chen et al., 1996). More and more people now emphasize the roles of manures in agriculture.

However, a series of problems were also raised from applications of manure, including the salt toxicity of manures to plant (Meek, 1974), and accumulation of trace metals in plant that may pose a health risk when humans or livestock consume them (Donahue, 1977). So, further evaluation of application of manure, especially from intensive farming, should be given. In China, the history of traditionally utilizing organic manures in farmland is long. However, with the rapid development of intensive farming in China, quantities of livestock and poultry excrements increased quickly and their constitutes varied a lot compared with that before. In 2002, a survey of the status of heavy metals pollution in livestock and poultry feeds and manures under intensive farming in Jiangsu province, China, was carried out in our laboratories (Cang et al., 2004). It was found that Cu and Zn concentrations in animal manures were high; for example, the Cu concentration in a pig manure sample reached as high as 1726 mg kg^{-1}. Nicholson et al. (1999) studied heavy metal contents of livestock feeds and animal manures in England and Wales, and also observed similar results. However, it is not clear what the results are when these manures containing high concentrations of heavy metals are applied in agricultural soil, especially in a long-term, because metal input through application of manures to soil will have a different behavior affecting soil chemistry and plant growth as well as metal uptake from the metals spiked in soil as metal sulfate (Miyazawa et al., 2002; Walker et al., 2003).

Nitrogen and phosphorus pollution as well as how to control wastewater and pathogeny contamination from breeding plants recently have been greatly concerned in China (Dong, 1998; Ding, 2000; Xu et al., 2002), but little attention was paid to heavy metal pollution of livestock and poultry feeds and manures; and there are limited information available about heavy metal inputs in agricultural soil *via* livestock and poultry manures. In this paper, different amounts of Cu and Zn from livestock and poultry manures, standing for the soil receiving the manure applied for different times to result in soil metal accumulation, were introduced in a garden soil to evaluate their effects on growth of radish and pakchoi as well as the uptake of Cu and Zn.

2. Materials and methods

2.1. Soil and manures

A surface (0–20 cm) garden soil (Luvisols) was sampled at Jiangnin county, Nanjing. Livestock and poultry manures samples, including a pig manure (PM), a chicken manure (CM) and a commercial organic manure (OM) were collected from intensive farming plants in the suburb of Nanjing. The soil and manures were air-dried, ground, and sieved to pass through a 1.0 mm mesh before use. Some physical and chemical properties of the tested samples were shown in Table 1. The pHs of the pig manure, chicken manure and organic manure were higher than that of the garden soil. The electric conductivities (EC) of the chicken manure and organic manure were higher than that of the pig manure and the soil, suggesting their possible salt toxicity to plants and soil organism.

2.2. Pot experiments

Pot experiments were carried out to examine the growth and metal uptake of radish and pakchoi in the garden soil by application of the manures containing different concentrations of Cu and Zn to simulate soil metal accumulation by manure application for different times, which were cultivated with different concentrations of $CuSO_4$ and $ZnSO_4$ solutions for 2 weeks prior to the

Table 1
Some physical and chemical characteristics of the garden soil and the livestock and poultry manures

Tested samples	pH	EC (ds m^{-1})	Total N (%)	Total P (%)	Total K (%)	Total Cu (mg kg^{-1})	Total Zn (mg kg^{-1})
Garden soil	5.03[a]	0.45[a]	0.19	0.12	4.55	28.9	85.2
Pig manure	7.29[b]	1.9[b]	1.09	1.85	2.70	19.8	106
Chicken manure	7.56[b]	3.0[b]	1.85	1.66	2.75	152	516
Organic manure	6.25[b]	3.3[b]	1.64	3.58	2.95	51.7	627

[a] 1:2.5 soil to water.
[b] 1:5 manure to water.

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