Effects of insect frass with different cadmium content on maize plant growth and cadmium accumulation

Ruijie Cai, Xiang Wu, Xiaobo Wang, Xiaoyan Xu*
College of Agronomy and Resource and Environment, Tianjin Agricultural University, Tianjin 300384, China

*Corresponding author e-mail: xuxy6699@163.com

Abstract. In order to explore the effect of cadmium in insect frass on the growth of maize, the pot experiment method was selected to investigate the effects of black soldier fly frass with different cadmium contents (0 mg·kg⁻¹, 2 mg·kg⁻¹, 12 mg·kg⁻¹, 28 mg·kg⁻¹) on maize plant height, chlorophyll content, photosynthetic rate and cadmium accumulation in plants. The results showed that there were no difference between treatments for maize plant height. Insect frass with 28 mg·kg⁻¹ cadmium contents improved chlorophyll content and photosynthetic rate at 30th day. Cadmium content in plants and roots increased significantly with increasing of cadmium content in insect frass. The highest Cadmium content of plants and roots were 0.32 mg·kg⁻¹ and 1.50 mg·kg⁻¹ respectively.

Keywords: Insect frass; Maize plant growth; Cadmium accumulation.

1. Introduction
With large-scale and intensive development of Chinese livestock and poultry breeding industry, a large amount of heavy metals have been added to the feed in order to prevent diseases of livestock and poultry and promote the growth of livestock and poultry, however most of the heavy metals have been excreted with the feces, insulting in serious excessive heavy metals in livestock and poultry feces [1].

The main source of heavy metals in agricultural production is caused by the massive application of livestock and poultry manure, and organic manures with chicken manure, pig manure, and cow manure have become the main source of soil heavy metal pollution [2, 3]. The total excess rate of soil heavy metals in China is 16.1%, of which the excess rate of cadmium is up to 7.0% [4]. Compared with other heavy metals cadmium has higher bioavailability, which is more likely to accumulate in crops [5], affect crop respiration [6] and photosynthesis, [7] inhibit the nutrient absorption of crops, which causing damage to crops. Results [5] showed that high cadmium concentrations can significantly inhibit the growth of wheat and cause harm to wheat. However, there were no report about effect of insect frass with cadmium content on plant growth. The accumulation of heavy metals in maize plants and its effect on the growth of maize were studied in this experiments, which providing a theoretical basis for the application of insect frass in agriculture and promoting the development of organic agriculture and green agriculture in China.
2. Materials and methods

2.1. Materials
This experiment was conducted in the net greenhouse of Tianjin Agricultural University. The soil physical and chemical properties were tested: pH value 8.27; electrical conductivity 367 μS cm⁻¹, organic matter content 23.85 g kg⁻¹, nitrate nitrogen content 28.97 mg kg⁻¹, and available phosphorus content 21.70 mg kg⁻¹, and the available potassium content 235.55 mg kg⁻¹. The tested maize variety is Zheng Dan 958. The tested black soldier fly frass are produced by black soldier fly transforming pig manure with different cadmium contents. The properties are showed in Table 1.

| Material       | Cadmium content (mg·kg⁻¹) | pH  | Organic matter content (%) | Nitrogen content (%) | Phosphorus content (%) | Potassium content (%) |
|----------------|---------------------------|-----|-----------------------------|---------------------|------------------------|-----------------------|
| Frass manure I | 0                         | 8.62| 72.88                       | 1.47                | 6.69                   | 2.03                  |
| Frass manure II| 2                         | 8.62| 78.34                       | 1.42                | 6.64                   | 1.99                  |
| Frass manure III| 12                        | 8.73| 73.74                       | 1.40                | 6.76                   | 1.97                  |
| Frass manure IV| 28                        | 8.6 | 76.36                       | 1.47                | 6.71                   | 2.01                  |

2.2. Experimental design
Maize pot experiment: T1 (applied insect frass manure I), T2 (applied insect frass manure II), T3 (applied insect frass manure III), and T4 (applied insect frass manure IV) were set up, and each treatment was repeated 4 times. The soil was filled with 6 kg, and the application amount of insect frass manure was 60 g·kg⁻¹. Seeding and routine management were performed on June 10, 2019. Maize plant samples were harvested on August 29, 2019, and dried for testing.

2.3. Measurement items and methods
The maize plant height was measured using a tape measure, and the chlorophyll content was measured using a pad-520 instrument. The heavy metal content of plants was determined by ICP-MS.

2.4. Data analysis
The experimental data were analyzed by Excel software, and the difference was analyzed by DPS 2000 data processing system.

3. Results analysis

3.1. Effects of different treatments on maize plant height, chlorophyll content, and photosynthetic rate
As shown in Figure 1, with the increase of time, the plant height of each treatment increased significantly. At the 70th day, the maize plant height increased by 83.25%, 84.17%, 80.32% and 82.22%, respectively, compared with that at the 30th day. At the same time, the increase of Cadmium content in insect frass manure had no significant effect on maize plant height.
As shown in Figure 2, with the increase of time, the chlorophyll content of maize decreased. At the 30th day, the chlorophyll content decreased by 31.25%, 30.91%, 23.85% and 47.48%, respectively, compared with that at the 70th day. At the 30th day, there was no significant difference of chlorophyll content between T2 and T1, T3 and T1 treatments. The chlorophyll content in T4 treatment was significantly higher than that in T1 treatment, with an increase of 6.06%. At the 50th day, the application of insect frass manure with different Cadmium contents had no significant effect on chlorophyll content. At the 70th day, there was no significant difference of chlorophyll content in each treatment.

As shown in Figure 3, with the increase of time, the photosynthetic rate of maize in each treatment decreased significantly. At the 30th day, the photosynthetic rate of maize decreased by 80.92%, 87.30%, 95.25% and 89.47%, respectively, compared with that at the 70th day. At the 30th day, with the increase of Cadmium content in insect frass manure, the maize photosynthetic rate increased, the photosynthetic
rate of T3 and T4 treatments increased by 6.86% and 6.38% compared to T1. At the 50th day, with the increase of Cadmium content in insect frass manure, the photosynthetic rate of maize decreased. The photosynthetic rate of T1 treatment was significantly higher than that of T2, T3 and T4, and there was no significant difference of photosynthetic rate between T2, T3 and T4 treatments. At the 70th day, there was no significant difference of photosynthetic rate of maize between insect frass manure treatments with different Cadmium content.

![Figure 3. Effect of different treatments on photosynthetic rate of maize](image)

3.2. Effects of different treatments on Cadmium content in maize plants

As shown in Table 2, with the increase of the Cadmium content in insect frass manure, the Cadmium content in the plants and roots of maize increased significantly. The plants Cadmium content in T3 and T4 treatments increased 15 times and 32 times, respectively, compared with T1. The Cadmium content in the roots of T4 treatment is the highest, 1.50 mg/kg, the Cadmium content in T1 treatment is the lowest, 0.05 mg/kg.

| Treatment | Cadmium content in maize |       |
|------------|--------------------------|-------|
|            | Plants                   | Roots |
| T1         | 0.01±0.001d              | 0.05±0.0008d |
| T2         | 0.02±0.003c              | 0.15±0.001c  |
| T3         | 0.15±0.010b              | 0.71±0.009b  |
| T4         | 0.32±0.003a              | 1.50±0.005a  |

4. Discussion

The level of chlorophyll content in plants will directly affect the strength of photosynthesis, and thus affect the growth and metabolism of plants [8]. Studies have shown that the application of insect frass manure can increase the plant height of tomato, which may be due to the higher content of organic matter in insect frass manure, which promotes the growth of tomato plants [9], which is consistent with the results of this study that fertilization treatments significantly increase plant height of maize. The results of this study showed that each fertilizer treatment significantly increased chlorophyll content and photosynthetic rate of maize, this is consistent with the conclusion that Wang Ligang et al. [10] found that the chlorophyll content of leaves increased significantly after the addition of organic fertilizer, which may be due to the fact that the availability of soil nutrients was improved after the application of
organic manure into the soil, which resulted in an adequate supply of soil nutrients, enhanced chlorophyll synthesis capacity, and increased chlorophyll content in leaves, thus improving the photosynthetic capacity[11]. The increase of Cadmium content in insect frass manure has no significant effect on plant height, chlorophyll content and photosynthetic rate in later stage of maize, which may be due to the low concentration of Cadmium in soil, so maize plants can rely on their own regulation system to alleviate Cadmium toxicity.

Cadmium has a strong potential hazard and can be absorbed and accumulated in different tissues of the crop. Studies by Lu Gan et al. [12] showed that under different levels of heavy metal, the heavy metal content of maize plants root was greater than that of stem leaf. The experimental research results are consistent, with the increase of Cadmium content in insect frass manure, the Cadmium content in the plants and roots of maize increased significantly. The Cadmium content of roots was higher than that of plants. It may be that the root system of maize has a retention effect on Cadmium, which reduces the transfer of Cadmium to the ground.

5. Conclusion
Insect frass manure with 28 mg•kg\(^{-1}\) cadmium contents improved chlorophyll content and photosynthetic rate at 30th day. The increase of Cadmium content in insect frass manure has no significant effect on the plant height, chlorophyll content and photosynthetic rate of maize at 70th day. Cadmium content in plants and roots increased significantly with increasing of cadmium content in insect frass manure. The highest Cadmium content of plants and roots were 0.32mg/kg and 1.50mg/kg, respectively.

Acknowledgments
This work was supported by the National Key Research and Development Program of China (2018YFD0500205), Tianjin Science and Technology Plan Project (19ZYYFSN00010, 18ZXYENC00130).

References
[1] Chen Z X,Dong L H,Yang Q,Wang Q,Chen X H,Zhang X X,Chen G Z(2019)Pollution of heavy metals in livestock and poultry faeces in China and its treatment measures. Modern Agriculture Research 11:42-43.
[2] Huang S W,Tang J W,Li C H(2017)Status of heavy metals,nutrients,and total salts in commercial organic fertilizers and organic wastes in China.Journal of Plant Nutrition and Fertilizer23(1):162-173.
[3] Jia W X,Wen J,Xu W L,Duan R,Zeng X B,Bai L Y(2016)Content and fractionation of heavy metals in livestock manures in some urban areas of China.Journal of Agro-Environment Science35(4):764-773.
[4] Ministry of Environmental Protection, Ministry of Land and Resources.(2014) Report on the national general survey of soil contamination. China Environmental Protection Industry 36(5);10-11.
[5] Zhang Q,Li R Y,Xu X H,Xie X J,Chambe E A(2019)Effects of cadmium pollution in soil on growth and cadmium uptake of wheat. Journal of Agricultural Resources and Environment 36(04):522-527.
[6] Hobbelen P H,Koolhaas J E,Gestel C A V(2006)Bioaccumulation of heavy metals in the earthworms Lumbricus rubellusand Aporrectodea caliginosa in relation to total and available metal concentrations in field soils. Environmental Pollution 144(2):639-646.
[7] Kirkham M B.(2006)Cadmium in plants on polluted soils:Effects of soil factors,hyper accumulation,and amendments.Geoderma137(1-2):19-32.
[8] Yang X D,Qu S X,Wu S Q,Zeng X B,Huang K T,Tong Z F(2019)Effects of Manganese stress on chlorophyll and Membrane Lipid peroxidation in sunflower seedling leaves. Anhui Agricultural Science Bulletin 25(16):10-11+42.
[9] Wu X,Hu C Y,Cai R J,Xu X Y,Wang J L,Wang X B(2019)Influence of Frass Organic Manure on
Tomato Growth and Quality. Northern Horticulture 3:60-64.

[10] Wang L G, Li W J, Qiu J J, Ma Y L, Wang Y C (2004) Effect of biological organic fertilizer on crops growth, soil fertility and yield. Soil and Fertilizer Sciences in China 5:12-16.

[11] Wang X Y, Fang L, Dai L (2019) Effects of Different Fertilizer Ratios on Photosynthetic Characteristics and Quality of Polygonatum odoratum. Northern Horticulture 18:128-133.

[12] Lu G, Li L M, Tao X Y, Liu X H, Si Y B (2017) Effects of lead and copper stress on growth, pigment content and heavy metal absorption in corn (Zea mays L.) Journal of Anhui Agricultural University 44(05):905-911.