Application of excess sludge extract from sewage treatment plant in garden flower planting

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Abstract. In order to explore the application effect of excess sludge extract from sewage treatment plant in garden flower planting, the extracts prepared from excess sludge and its fertilizer efficiency were evaluated and its effects on plant height, stem diameter, flower yield and diameter and plant weight of Impatiens balsamina were studied by pot experiments, which provided reference for the resource utilization of excess sludge. The results showed that the initial solution content of amino acid in excess sludge extract was 3.6%, and the total amount of microelement was 66.46 ppm. It was fully soluble, slightly alkaline, and the harmful elements As, Cd, and Pb did not exceed the content of the standard. Although the total amount of amino acids and microelement was lower than the standards of amino acid-containing foliar fertilizers in China, it can meet the requirement of foliar fertilizer dilution in the market and can be used as amino acid foliar fertilizer after dilution. The appropriate concentration of excess sludge extract can promote the growth of Impatiens balsamina significantly, and the application effect was close to or better than some foliar fertilizer products in the market. The best concentration was 600 times diluted excess sludge extract. If the excess sludge extract is further prepared into amino acid foliar fertilizer, the effect will be better, it can be applied in garden flower planting, and can provide a new way for the resource utilization of excess sludge in sewage treatment plant.

1. Introduction
Excess sludge is the waste discharged by sewage treatment plants [1-2]. According to reports, the amount of urban sludge in China has exceeded 60 million tons in 2020 [3]. The discharge of excess sludge has brought huge environmental pressure to the sewage treatment plant, and the sludge problem has been very prominent [4]. Excess sludge is rich in various nutrients for plant growth, and its protein content reaches 30%-50% of dry weight [5]. It has the potential of resource utilization and is an excellent resource of amino acid foliar fertilizer. Therefore, the application of amino acid foliar fertilizer prepared from excess sludge in agriculture and forestry can not only widen the raw materials of amino acid foliar fertilizer, reduce the production cost, but also realize the resource utilization of excess sludge in sewage treatment plant. Because excess sludge is rich in N, P, K and other nutrients, it can be used as fertilizer in agriculture and forestry. Many researches had been carried out in this field. Li et al. (2009) [6], Latare et al. (2014) [7] and Zhang et al. (2014) [8] carried out the application of excess sludge as fertilizer directly in agriculture and forestry. Cai et al. (2010) [9], Xue et al. (2013)
[10], Yang et al. (2016) [11] and Lian et al. (2018) [12] carried out excess sludge composting. Ma et al. (2019) [13], Hu et al. (2015) [14], Deng et al. (2019) [15] and Zhang et al. (2019) [16] carried out the preparation of agricultural and forestry cultivation matrix from excess sludge and other materials. However, at present, the researches on excess sludge mainly focused on direct application, composting and cultivation substrate. There are few studies on the application of the excess sludge in the garden flower planting. Therefore, the excess sludge was extracted and its fertilizer effect was evaluated in this paper. Taking the garden plant (*Impatiens balsamina*) as the test material, the effect of application of the excess sludge extract on the growth index of *Impatiens balsamina* was studied through pot experiments, and the possibility of its application was evaluated, which provided a reference for the preparation of amino acid foliar fertilizer and its application of excess sludge from sewage treatment plant in the garden and the realization of the resource utilization of excess sludge.

2. Experimental materials and methods

2.1. Experimental materials

*Impatiens balsamina* was selected as the test material. The soil samples were collected from an abandoned land in Luoping village, Huaxi District, Guiyang City, Guizhou Province and a natural forest land in the campus of Guizhou Minzu University. The abandoned land and forest land soil were mixed evenly according to the ratio of 2:3 by mass, and they be used after passing 20 meshes. The basic physical and chemical properties of the tested soil showed in Table 1. For the sludge extract, refer to the hydrolysis of sludge with hot alkali solution proposed by Xiao et al. (2008) [17], Cui et al. (2009) [18] and Sheng et al. (2013) [19]. As the potassium content of sludge is generally low [20], In our experiment, NaOH was changed into 6 mol/L KOH solution as extracting agent. According to the solid-liquid ratio of excess sludge: extracting agent 1:8, hydrolysis time 10 h, temperature 100 ℃. After filtration, the filtrate was the excess sludge extracting solution used in our experiment. The determination of nutrients of excess sludge extracting is shown in table 2. The comparative foliar fertilizer was a water-soluble fertilizer containing amino acid produced by a company on sale.

| Items       | pH      | Organic matter (%) | Total nitrogen (g/kg) | Total phosphorus (g/kg) | Total potassium (g/kg) | Available phosphorus (mg/kg) |
|-------------|---------|---------------------|-----------------------|-------------------------|------------------------|-------------------------------|
|             | 6.78    | 12.25               | 0.78                  | 1.35                    | 9.29                   | 15.87                         |

2.2. Methods

The pot experiment was carried out in the greenhouse from May to August 2019. The plastic flowerpots used in the experiment were 25 cm high, 28 cm diameter and 4 kg soil per pot. In the pot experiment, six treatment groups were set up, which were 800 times (S1), 700 times (S2), 600 times (S3), 500 times (S4), 400 times (S5) of excess sludge extract dilution, respectively, and SS of commercial foliar fertilizer. The control group was clear water (CK). Each treatment was set up with three repetitions. Ten seeds were planted in each pot respectively. When the plant height was about 10 cm, three plants with strong growth and no diseases and insect pests were kept for experiment. These plants were sprayed once every 7 days, 250 ml in each pot, 10 times in total. During the period, watered and killed insects according to the daily management, and observed and recorded the growth state of plants.

2.3. Measured items

In the experiment, the plant height, stem diameter, flower diameter, yield and plant weight of *Impatiens balsamina* were measured. Organic matter, pH value, total nitrogen, total phosphorus, total potassium and available phosphorus were measured for the soil. Protein, amino acid, heavy metal and microelement were determined for the excess sludge extract.
3. Results

3.1. Evaluation of fertilizer efficiency of excess sludge extract

Table 2. The contents of nutrients and heavy metals in excess sludge extract

| Items                              | National standards | Excess sludge extract |
|-----------------------------------|--------------------|-----------------------|
| Amino acid content, %             | ≥10.0              | 3.6                   |
| Total amount of microelement (Fe, Mn, Cu, Zn, Mo, b) (in elements), % | ≥2.0               | 0.01                  |
| Water insoluble matter, %         | ≤5.0               | Fully soluble         |
| pH                                | 3.5-8              | >8                    |
| Harmful elements                  |                    |                       |
| As, %                             | ≤0.002             | ≤0.002                |
| Cd, %                             | ≤0.002             | ≤0.002                |
| Pb, %                             | ≤0.01              | ≤0.01                 |

The standards of amino acid-containing foliar fertilizer (GB / T 17419-1998) and the determination results of the extract showed in Table 2. The standard stipulates that the amino acid content is higher than 10%, and the amino acid content of the excess sludge extract was 3.6%. According to the standard, the total amount of microelement is higher than 2.0%. The contents of Fe, Mn, Cu, Zn, Mo and B in the extract were 34.36 ppm, 0.88 ppm, 0.39 ppm, 29.09 ppm, 1.01 ppm and 0.73 ppm respectively, and the total amount of microelement was 66.46 ppm. The requirement of water insoluble substance is lower than 5.0%, and the extract was fully soluble. The pH value was alkaline, which was higher than the specified 3.5-8. The requirements for harmful elements As and Cd are lower than 0.002% and Pb lower than 0.01%. The content of As in the extract was 0.14 ppm, Cd was 0.002 ppm and Pb was 0.29 ppm. The harmful elements did not exceed the requirements of foliar fertilizer standard.

The results showed that the content of amino acids and the total amount of microelement were lower than the standard of foliar fertilizer containing amino acids, the pH value was higher than 8, and the harmful elements were far lower than the standard. In terms of amino acids and microelement, the original solution did not meet the requirements of foliar fertilizer containing amino acids. In order to meet the requirements of amino acid content, the extract was concentrated. However, in the process of concentration, it was found that the liquid would solidify after being concentrated for a certain time, which was not convenient for subsequent use. Therefore, the excess sludge extract was not concentrated in this study.

3.2. Effects of excess sludge extract application on plant height of Impatiens balsamina

Figure 1. Effects of different concentration of excess sludge extract on plant height of Impatiens balsamina
As we can see from Figure 1, in the growth period of *Impatiens balsamina*, the plant height of S3 treatment group sprayed with 600 times diluted excess sludge extract and SS treatment group sprayed with commercial foliar fertilizer was the best, the height at harvest was 55.2 cm and 55.0 cm respectively, the difference between the two was not significant, compared with that of CK (44.6 cm) in clear water control group, it was increased by 19.20% and 18.91% respectively. During the whole growth period, there was no significant difference in the height of CK between S1 and S2 treatment group and clear water control group. The height of CK was 45.3 cm and 47.3 cm respectively, which was still higher than that of clear water control group. The height of S4 treatment group was 50.6 cm, 11.86% higher than that of clear water control group, while that of S5 treatment group was 39.9 cm, lower than that of clear water control group. It can be seen that the plant height of *Impatiens balsamina* showed a trend of increased first and then decreased with the increase of spraying concentration of excess sludge extract in all treatment groups. Among them, the 600 times diluted solution of excess sludge extract was the optimal spraying concentration. If the spraying concentration of excess sludge extract continues to increase, the plant will suffered from drug damage, which will lead to plant wilt and affected its normal growth. The higher concentration can cause damage to plant.

3.3. Effects of excess sludge extract application on stem diameter of *Impatiens balsamina*

In Figure 2, in the early growth stage of *Impatiens balsamina*, the stem diameter of S3 treatment group was the thickest, which was similar to the effect of SS treatment group, and was superior to other treatment groups. At the later stage of growth, the effect of S4 treatment group was the best, the stem diameter was 1.17 cm, which increased by 33.33% compared with CK (0.78 cm) of clear water control group, while that of S2 and S3 treatment groups was 1.12 cm, 1.10 cm, which increased by 30.36% and 29.09% compared with that of clear water control group, and it was also better than SS treatment group (0.99 cm). In the whole growth period, all the treatment groups sprayed with sludge extract were significantly better than the control group, and with the increased of the concentration of excess sludge extract, the stem diameter of the plant also showed a trend of increased first and then decreased, which was consistent with the plant height rule of *Impatiens balsamina*, indicated that sprayed the appropriate concentration of excess sludge extract can promote the healthy growth of *Impatiens balsamina*, which was beneficial to the growth of *Impatiens balsamina*. The application effect of 500 times diluted excess sludge extract was the best, which was better than the commercial foliar fertilizer.
3.4. Effects of excess sludge extract application on the yield and flower diameter of *Impatiens balsamina*

![Figure 3. Effects of different concentration of excess sludge extract on flower yield and diameter of *Impatiens balsamina*](image)

In Figure 3, the flower diameter of *Impatiens balsamina* with different concentration of excess sludge extract was as follows: SS (4.12 cm) > S3 (4.08 cm) > S4 (4.05 cm) > S2 (4.05 cm) > S5 (4.03 cm) > S1 (3.86 cm) > CK (3.85 cm). The flower diameter of *Impatiens balsamina* treated with different concentration of excess sludge extract was smaller than that of SS treated with commercial foliage fertilizer, however, S1, S2, S3, S4 and S5 treated groups Compared with the control group, the flower diameter increased by 0.14%, 4.94%, 5.71%, 4.94% and 4.55%, respectively. Therefore, the flower diameter of *Impatiens balsamina* also increased first and then decreased with the increase of the concentration of excess sludge extract spray. Another important indicator of flower quality was flower yield, which includes fresh weight and dry weight. Figure3 showed that the fresh weight and dry weight of *Impatiens balsamina* flowers in each treatment group were the same after sprayed different concentrations of excess sludge extract, which were SS>S3>S4>S2>S1>CK>S5. Among them, the fresh weight and dry weight of S3 treatment group were the best, which can be about 2 times of that of the control group with clear water, but lower than the flower yield of commercial foliar fertilizer. The fresh weight and dry weight of S1, S2 and S4 treatment groups were higher than that of the water control group, while the S5 treatment group was much lower than that of the water control group. The results showed that sprayed the appropriate concentration of excess sludge extract can improve the flower yield and promote the development of flowers, and the 600 times diluted use of excess sludge extract was the best spraying concentration to improve the quality and ornamental value of flowers, and its effect was similar to that of SS treatment group. However, in the S5 treatment group, The plant was damaged because of the excessive spraying concentration, which directly damaged the flower bud, affected the development degree of the flower and made the flower yield smaller than that of the control group, thus affecting the flower quality.

3.5. Effects of excess sludge extract application on plant weight of *Impatiens balsamina*

It can be seen from Table 3 that the plant weight of *Impatiens balsamina* treated by different spraying concentrations of excess sludge extract from high to low was as follows: S4>SS>S3>S2>S1>S5>CK. The plant weight of S4 treatment group (41.42 g) was the largest, which was better than that of SS treatment group (39.60 g), and there was significant difference between S4 treatment group and clear water control group (15.00 g), which was 63.79% higher than that of clear water control group. The plant weight of S1, S2, S3 and S5 treatment groups were 27.39 g, 30.42 g, 36.42 g and 21.58 g respectively, which were superior to that of the control group with clear water. It can be seen that the excess sludge extract can promote the growth of *Impatiens balsamina*. With the increased of the spraying concentration of the excess sludge extract, the plant weight of *Impatiens balsamina* first
increased and then decreased. The best spraying concentration was 500 times diluted excess sludge extract.

Table 3. Effects of different concentration of excess sludge extract on plant weight of *Impatiens balsamina*

| Treatment | plant weight (g)       |
|-----------|------------------------|
| CK        | 15.00±0.20e            |
| S1        | 27.39±1.92c            |
| S2        | 30.42±1.70c            |
| S3        | 36.42±1.28b            |
| S4        | 41.42±3.26a            |
| S5        | 21.58±1.28d            |
| SS        | 39.60±4.62ab           |

4. Discussion

There are many kinds of foliar fertilizer, and the classification methods are not uniform. According to the differences of the specific components of foliar fertilizer, Ministry of agriculture of China divided foliar fertilizer into five categories: macroelement water soluble fertilizer, microelement water soluble fertilizer, amino acids-containing water soluble fertilizer, humic acid-containing water soluble fertilizer, Agroforestry superabsorbent polymer and others. According to the function, foliar fertilizer can also be divided into nutrient type and regulation type. In this study, the content of amino acids in the excess sludge extract was 3.6%, the total amount of microelement was 66.46 ppm, it was fully soluble, the pH was higher than 8, and the content of harmful elements As, Cd and Pb were far lower than the specified standard. Compared with the standard of amino acid water-soluble fertilizer issued by the Ministry of agriculture of China, although the amino acid and microelements in the extract were lower than the standard, the amino acid water-soluble fertilizer developed on the market needs to be diluted 500-1000 times before application. Wang et al. (2011) [21] showed that the spraying concentration of foliar fertilizer was 500-600 times; Wang(2016) [22] indicated that the water-soluble fertilizer containing amino acid should be diluted by 1000 times. It can be seen that the content range of amino acid and microelements in amino acid foliar fertilizer is 0.01% - 0.02% and 0.002% - 0.004%, which can meet the requirements. According to the current dilution ratio of amino acid foliar fertilizer, the original solution of the excess sludge can be used as foliar fertilizer after being diluted 180-360 times.

The pot experiments showed that the application of 500 times diluted excess sludge extract made the growth of stem diameter and plant weight of *Impatiens balsamina* the best, which were 33.33% and 63.79% higher than that of the control group, and the application effect was better than that of the commercial foliar fertilizer. Among all the treatment groups sprayed with excess sludge extract, the effect of plant height in the whole growth period was the best when it was 600 times diluted with excess sludge extract, which increased by 19.20% compared with the control group when it was collected, indicated that the application of excess sludge extract could promote the plant height, stem diameter, flower yield, flower diameter and plant weight of *Impatiens balsamina*, which was similar to the results demonstrated by Liao et al. (2013) [23], Yuan et al. (2006) [24], Sheng et al. (2019) [25] and Fan et al. (2010) [26]. When sprayed 400 times of the excess sludge extract to dilute the solution, it may be because the amino acid, microelements and K and other nutrients in the sludge extract were too high, resulting in the damage phenomenon, which significantly reduced the plant height and flower diameter of *Impatiens balsamina*. Similarly, Gao et al. (2009) [27], Wang et al. (2015) [28] and Jaksomsak et al. (2018) [29] also obtained the same results. Therefore, in the application, it is also necessary to pay attention to the spraying concentration of the excess sludge extract. The best dilution ratio of the sludge extract was 600 times in our research.

From the above analysis, the excess sludge extract can significantly promote the plant height, stem diameter, plant weight, flower yield and flower diameter of *Impatiens balsamina*. The application
effect of stem diameter and plant weight was close to or better than that of commercial foliar fertilizer, and the plant height and flower yield were better than that of clear water control group. Therefore, it is feasible to use the excess sludge extract as foliar fertilizer. If the excess sludge extract is further compounded, it will have better effect on garden flowers.

5. Conclusions
The application of excess sludge extract can promote the plant height, stem diameter, plant weight, flower yield and flower diameter of *Impatiens balsamina*, and the effect was similar to or better than some foliar fertilizers on sale. The further preparation of amino acid foliar fertilizer which can meet the standard of China has a good prospect of development and application. It can be widely used in garden plants, and provides a new way for sludge utilization of sewage treatment plants.

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