Effects of insect frass and distiller’s grains on physicochemical properties of saline alkali soil

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Abstract. In this study, a pot experiment was conducted to study the effect of black soldier fly feces and distiller’s grains on the physicochemical properties of moderate saline alkali soil. Results showed that the application of insect feces and distiller’s grains significantly increased the contents of nitrate nitrogen, available phosphorus, available potassium and organic matter in the soil, and reduced soil pH. After the treatment of 2% insect feces mixed with 2% distillates, the available nitrogen content of saline alkali soil was the highest, which was 95.74% higher than that of the control. It can be seen that the combination of 2% insect feces and 2% distiller's grains was best suited to improve the saline alkali soil properties under the condition of this experiment.

Keywords: Saline alkali soil; Black soldier fly feces; Distiller’s grains; Physicochemical properties of saline alkali soil.

1. Introduction

Around 99.13 million hectares are covered with saline alkali soil in China [1], and the number is constantly rising. Thus, the amelioration of saline alkali land has become one of the urgent environmental issues. Abundant evidence showed that the application of organic fertilizer can improve the physicochemical properties of saline alkali soil [2, 3]. As a new type of organic fertilizer, insect frass has a higher content of organic matter, whereas its use has been scarcely addressed.

Distiller’s grains, major by-products yielded in winemaking process, contain sufficient nutrient substance [4]. Studies suggested distiller’s grains markedly improve the physicochemical properties of saline alkali soil in terms of soil pH and organic content [5], but the performance of insect feces mixed with distiller’s grains has not been reported so far. Our research was to determine the effect of single and combined application of black soldier fly frass and distiller’s grains on the physicochemical properties of saline alkali soil, aiming to provide theoretical basis for resource utilization of insect feces and wasted distiller’s grains as well as amelioration of saline alkali soil.
2. Materials and methods

2.1. Materials
Soil samples were taken at the depth of 0-20 cm from Dagang Farm in Tianjin. Physicochemical properties of soil and organic fertilizers are described in Table 1 and Table 2, respectively.

| Table 1. Physicochemical properties of soil samples. |
|-----------------------------------------------|
| pH | Organic matter (g/kg) | Nitrate nitrogen (mg/kg) | Available phosphorus (mg/kg) | Available potassium (mg/kg) |
| 8.30 | 10.50 | 14.48 | 20.22 | 331.89 |

| Table 2. Properties of black soldier fly frass and distiller’s grains. |
|-----------------------------------------------|
| Organic fertilizer | pH | Organic matter (g/kg) | Total nitrogen (mg/kg) | Total phosphorus (mg/kg) | Total potassium (mg/kg) |
| Black soldier fly frass¹ | 8.64 | 66.27 | 4.27 | 3.78 | 3.00 |
| Distiller’s grains² | 5.50 | 82.27 | 3.03 | 0.54 | 0.30 |

¹ Transformation of chicken manure, self-made.
² Taken from a distillery in Jinan, Shandong Province.

2.2. Experimental design
A pot experiment was carried out in the net house of Tianjin Agricultural University on Jul. 1, 2019. The diameter of the plastic pot was 30 cm and height 25 cm. Each pot was filled with 6 kg of saline alkali soil. Four treatments were set up based on the content and type of fertilizer: CK (0), T1 (4% of black soldier fly feces), T2 (2% of black soldier fly feces and 2% of distiller’s grains), T3 (4% of distiller’s grains). Three pots were assigned to each treatment. Tested soil was mixed for each treatment on Sept. 20 for further analysis.

2.3. Methods
Soil pH was measured with pH meter. Content of organic matter was measured by the potassium dichromate method. Soil nitrate nitrogen was measured by ultraviolet spectrophotometry. Available phosphorus was measured by molybdenum blue colorimetry and available potassium by flame photometric method [6].

2.4. Data analysis
Experimental data was analysed by Microsoft Excel. Statistical difference was analysed using SPSS 17.0 (P < 0.05).

3. Results

3.1. Effect of black soldier fly feces and distiller’s grains on pH and salinity of saline alkali soil

3.1.1. Effect on pH of saline alkali soil. T1, T2 and T3 significantly decreased soil pH (Figure 1). The pH value of T3 was the lowest, which declined by 5.52% compared to the control. There was no significant difference between T2 and T3. This indicates that the combined application of insect feces and distiller’s grains effectively lowers pH of saline alkali soil. The single usage of distiller’s grains and the combined application performed best in decreasing soil pH.
3.1.2. Effect on salinity of saline alkali soil. T1, T2 and T3 significantly increased salinity (Figure 2). Salinity of T1 was the highest, which went up by 92.31% compared to the control. Salinity of the soil treated by T2 and T3 showed no significant difference, which improved by 42.67% and 33.88%, respectively.

3.2. Effect of black soldier fly feces and distiller’s grains on contents of organic matter, nitrate nitrogen, available phosphorus and available potassium in saline alkali soil

3.2.1. Effect on content of organic matter in saline alkali soil. Organic matter significantly grew after treated with fertilizers (Figure 3). The increase in organic matter was highest for T3, followed by T2 and T1, which implies distiller’s grains plays a major role in raising organic content. Compared to the control, organic matter increased by 40.13%, 54.05% and 74.11% for T1, T2 and T3, respectively.
3.2.2. **Effect on nitrate nitrogen content in saline alkali soil.** All the treatments significantly increased the content of nitrate nitrogen (Figure 4). Nitrate nitrogen content of T2 was the highest, which rose by 95.74% compared to the control, while it increased by 61.89% and 51.04% for T1 and T3, respectively. There was no significant difference between T1 and T3. This suggests that nitrate nitrogen effectively accumulates after the combined application of insect frass and distiller’s grains.

3.2.3. **Effect on available phosphorus content in saline alkali soil.** Available phosphorus significantly grew after treated with fertilizers (Figure 5). The increase was highest for T1, followed by T2 and T3, which implies insect feces substantially increased available phosphorus content. Compared to the control, available phosphorus improved by 607.26%, 492.17% and 266.19% for T1, T2 and T3, respectively.
3.2.4. Effect on available potassium content in saline alkali soil. Available potassium significantly grew after treated with fertilizers (Figure 6). Available potassium content of T1 was the highest, which rose by 198.24% compared to the control, while it increased by 84.36% and 30.21% for T2 and T3, respectively. It turns out that insect frass has the strongest effect on increasing available potassium content and the combined application of both fertilizers comes second.

4. Discussion
Most plants do not grow well in saline alkali habitats due to the higher levels of salinity and pH, and less organic matter. Studies have shown that the physical structure and permeability of saline alkali soil can be improved by mixing wasted vinegar residue, furfural residue, distiller’s grains, etc. Thus, the efficiency of desalination increased and consequently, alkalinity declined [5]. It has been demonstrated that the combination of desulfurized waste (mainly CaSO₄·2H₂O) and conditioner (primarily furfural residue, wasted coal cinder, straw powder and organic fertilizer) can greatly improve the structure of the plow layer and loose soil. Therefore, the permeability and adsorption were enhanced, while pH value and total salt content dropped [7]. This was also verified by Zhang J S et al [8]. Distiller's grains effectively moderate the alkalinity and reduce soil pH due to their lower pH ranging from 3 to 4. Our results showed that T1 (4% of black soldier fly feces), T2 (2% of black soldier fly feces and 2% of distiller’s grains) and T3 (4% of distiller’s grains) significantly reduced soil pH and increased the
contents of nitrate nitrogen, available phosphorus, available potassium and organic matter. This was caused by a higher content of organic matter in the feces and distiller’s grains applied in the soil [9]. The pH value of T3 was lowest and declined by 5.52% compared to the control. For T1 and T2, pH declined by 1.82% and 3.97% respectively. This could be explained by the acidic nature of distiller’s grains, which significantly improved soil permeability and thus a stronger effect on desalination. The nitrate nitrogen content of T2 was the highest, which was 95.74% higher than that of the control, indicating a combined application of feces and distiller’s grains is the finest option for increasing soil available nitrogen, although the optimal ratio still needs to be further tested.

5. Conclusion
The application of black soldier fly frass and distiller’s grains significantly increased the contents of nitrate nitrogen, available phosphorus, available potassium and organic matter in the soil, and reduced soil pH. After the treatment of 2% insect feces mixed with 2% distillates, the available nitrogen content of saline alkali soil was the highest, which was 95.74% higher than that of the control. In summary, the application of insect feces and distiller’s grains can improve saline alkali soil properties. Under the condition of this experiment, 2% of insect frass and 2% of distillates were best used to improve the saline alkali soil.

Acknowledgments
This work was supported by the National Key Research and Development Program of China (2018YFD0500205), Tianjin Science and Technology Plan Project (19ZFYFSN00010, 18ZXYENC00130).

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