Effects of Different Mechanized Organic Fertilization Methods on Soil Enzymes Activities in a Corn Field

Qiping Dong1, a, Xin Cheng1, a, Siwei Zhang1, a, Chunming Bai2, a, Di Wu1, a, Xinyue Liu1, a, Zhiyu Sun1, a, Qiaobo Song1, Qingwen Shi1, Yifei Liu1, * and Xiaori Han1, *
1Shenyang Agricultural University, Shenyang, China
2Liaoning Academy of Agricultural Sciences, Shenyang, China
aJoint first authors
*Co-corresponding author e-mail: liuyifeiscience@163.com

Abstract. In this experiment, continuous cropping corn brown soil of three years as the research object. It was explored that the different mechanized organic fertilizer on the main soil enzyme activities in several agricultural productions, which is in order to boil down the soil fertilization and improvement methods for reference. Tillage and fertilization were carried out before and after sowing and harvesting, and soil samples were collected and analyzed regularly at different growth stages. We found that the increment of soil enzyme activities by various mechanized organic fertilization methods was significantly higher than that of conventional fertilizer application in a corn growth period or in the whole corn growth period. Among them, mechanization of rotting cow dung and returning straw to the field can obviously improve the activities of soil urease and phosphatase. The mechanical application of soil sucrose enzymes to mature cow dung was the best, followed by straw returning to the field. In addition, mechanized application of straw to the field can significantly increase the activities of catalase and cellulase in the soil.

1. Introduction
It is well known that soil fertility directly affects crop yield, and soil enzyme, which has the strongest physiological activity in soil, has an important effect on soil fertility. Soil enzyme is secreted by soil microorganisms, animals and plants, its residues are stable protein with special catalytic activity [1], and its catalytic activity is tens or even hundreds times higher than that of inorganic catalysts[2]. Soil enzyme is involved in many biochemical reactions of soil, and its activity directly affects the release of available nutrients in the soil. For example, studies have shown that urease in soil is involved in the decomposition of organic matter, the formation of ammonia and carbon dioxide, which affects the decomposition and transformation of urea in the soil, and the ability of soil to supply nitrogen [3]. The activity of phosphatase can indicate the transformation of soil organophosphorus, and the conversion of soil organophosphorus can be inferred from the activity of protease [4]. Cellulose can be used as an important index to characterize soil carbon cycling speed. Catalase is closely related to the conversion rate of soil organic matter, sucrase and its product glucose affect soil respiration [5,6]. At present, the decline in soil quality caused by improper fertilization is still very obvious in agricultural production. In order to increase production in the current season and apply a certain chemical fertilizer blindly, the balance of soil enzymes will be destroyed. Some studies have shown that fertilizer can inhibit the activity of phosphatase [7]; excessive application of nitrogen fertilizer can inhibit the activity of urease...
in soil [8]; excess fertilizer of nitrogen, phosphorus and potassium can inhibit the activity of catalase in soil [9]. However, the appearance of organic fertilizer has reversed this trend. A large number of studies have shown that organic fertilizer has a great influence on soil enzyme activity and is also regarded as one of the indicators of soil fertility[10]. Therefore, it is of great significance to establish a scientific and reasonable way of soil fertilization in terms of agricultural production and environmental protection.

2. Material and method

2.1. Experimental material

2.1.1. Corn variety for the experiment: Shenghe 18

2.1.2. Experimental setting: Northern temperate continental monsoon climate in Lujiafangshen Village (N42 °16CU E 123 °23'), Dagujiazi Town, Faku County, Shenyang City, Liaoning Province, with a relatively large annual temperature difference.

2.1.3. Soil type: It is brown soil. The basic characteristics are shown in the table below.

| Soil texture | pH  | Bulk density (g/cm³) | Organic matter (g/kg) | Total N (g/kg) | Total P (g/kg) | Total K (g/kg) | Available N (mg/kg) | Available P (mg/kg) | Available K (mg/kg) |
|--------------|-----|---------------------|-----------------------|----------------|---------------|---------------|---------------------|---------------------|---------------------|
| Brown soil   | 5.06| 1.39                | 11.89                 | 2.3            | 0.12          | 15.92         | 100.8               | 19.28               | 141.44              |

2.1.4. Experimental fertilizers: (1) Organic fertilizers.

| Organic fertilizer variety | Organic C C% | Total N N% | Total P P₂O₅% | Total K K₂O% | Water % |
|----------------------------|--------------|------------|--------------|-------------|--------|
| Rotten cow dung            | 33.81        | 2.41       | 1.919        | 1.455       | 58.29  |
| Corn stalk                 | 43.54        | 0.863      | 0.260        | 0.834       | 9.07   |
| Granular fertilizer as biochar-based | ≥45%        | 2.06       | 1.82         | 1.78        | 25-30  |

(2) Conventional chemical fertilizer: base fertilizer (N, P, K: 27-11-13), oral fertilizer (N, P, K, 15-15-15).

(3) Fungicides: to help the straw rot.

2.1.5. Machinery for test: (1) conventional field fertilizer sprayer (2) single disc sower (3) straw mechanical shredding (long 5-10cm) (4) 55 / 60 horsepower tractor.

2.2. Test methods

2.2.1. Experimental processing arrangements: The experiment was divided into 5 treatments for three years. Fertilization and tillage were carried out before and after crop sowing and harvesting. Soil samples (0–20cm soil layer) were collected at an early stage, seedling stage, jointing stage, heading stage, maturity stage and soil samples were collected to analyse the changes in soil enzyme activities. Five experimental zones were established for our experiments: Zone I (mechanical application of decayed cow manure, each mu was sprayed with 500kg air-dried base; water content 20%, ridge top rotation tillage 20cm); Zone II (mechanical cutting and crushing for stalk returning first and then
rotary tillage 20cm over ridges, 400kg per mu, with straw-decomposing inoculant and chemical nitrogen fertilizer, sprayed simultaneously by single factor; Zone III (mechanical cutting and crushing for stalk returning first and deep tillage for 30cm further, 400kg per mu, with straw-decomposing inoculant and chemical nitrogen fertilizer, sprayed simultaneously by single factor); Zone IV (mechanical application of Granular fertilizer as biochar-based), Zone V (conventional management of tillage and fertilizer application, for which 18kg nitrogen, 5kg phosphorus pentoxide, 6kg potassium oxide, urea and potassium chloride 20kg+10kg as the basic fertilizer, 10kg diammonium phosphate as the seed fertilizer, extra fertilization for 225kg/hm at bell stage.)

2.2.2. Determination of soil enzyme activity: The specific methods for the determination of soil enzymes were as follows: the activity of soil urease was determined by indophenol blue colourimetry, and the activity was expressed as mg NH\textsubscript{3}N/g (37 °C for 24 h), and the acid phosphatase in soil was determined by disodium phosphate colourimetry. The activity was expressed by the mass (mg) of phenol released from 1 g soil after 24 hours, and the activity of sucrase was determined by the colourimetric method of 3,5-dinitrosalicylic acid, and the activity was expressed as mg glucose/g (37 °C for 24 h). The activity of soil cellulase was determined by the colourimetric method of 3, 5-dinitrosalicylic acid, and the activity of catalase was determined by potassium permanganate titration. The activity of catalase was expressed as mL (0.1mol/L KMnO\textsubscript{4}) / g (4 °C for 1 h) [10].

3. Results and analysis

3.1. Effects of different Mechanized Organic Fertilization methods on soil urease activity

![Urease activity graph](image)

Figure 1. Effects of different treatments on soil urease activity on different stages
With the growth of corn, the soil urease activity of all treatments increased from Seedling stage to Tasselling stage and then decreased. The average value of urease activity was Zone I (0.97 ±0.034a) > Zone IV (0.97 ±0.081a) > Zone II (0.86 ±0.015ab) > Zone III (0.81 ±0.083b) > Zone V (0.80 ±0.075b), and the most obvious difference was between the treatments at the tasselling stage of corn.

3.2. Effects of different mechanized organic fertilization methods on soil acrylate phosphatase activity
According to the different growth stages of corn, the average value of soil acid-type phosphatase activity under different treatments was compared. Zone I (0.9468 ±0.014 a) > Zone II (0.9458 ±0.035 a) > Zone IV (0.9221 ±0.015 ab) > Zone III (0.8972 ±0.025 b) > Zone V (0.8279 ±0.017 c). The soil phosphoric acid activity of organic fertilizer treatment was significantly higher than that of conventional fertilizer treatment except at the Seedling stage.

3.3. Effects of different mechanized organic fertilizer methods on cellulase activity

The changing trend of soil cellulase activity under different treatments was basically the same, showing the trend of rising from seedling emergence stage to tasselling stage, and then decreasing trend of soil cellulase activity. The average values of II were (0.254 ±0.02a) > (0.246 ±0.01a) > IV (0.244 ±0.01a) > III (0.223 ±0.01b) > V (0.196 ±0.04c). The effect of mechanized organic fertilizer on the increase of soil cellulase activity was significantly higher than that of conventional treatment, among which straw returning to the field was the best.

3.4. Effects of different mechanized organic fertilization methods on the activity of catalase
Figure 4. Effects of different treatments on soil hydrogen peroxidase activity on different stages

The change of soil catalase activity under different treatments showed the regularity that the activity of catalase increased first from seedling stage to tasselling stage, and then decreased. The average value of soil catalase activity during corn growing period: II (1.91 ±0.011 a) > I (1.84 ±0.009 b) > IV (1.71 ±0.037 c) > V (1.64 ±0.043 d) > III (1.37 ±0.096 e).

3.5. Effects of different mechanized organic fertilization methods on soil sucrose enzyme activity

Figure 5. Effect of different treatments on soil invertase activity on different stages of corn

The changes in soil sucrase activity with corn growth period increased first and then decreased under different treatments. The average value of soil sucrase activity during corn growing period: I (10.22 ±0.19a) > IV (9.00 ±1.70 ab) > III (8.91 ±0.20 ab) > II (8.39 ±0.06a) > V (7.27 ±0.29 c). The effect of organic fertilizer culture on soil sucrase activity was significantly higher than that of common fertilization treatment.

4. Conclusion

4.1. Mechanization was effective in improving soil urease activity

The results were as follows: For improving soil urease activity, the effect of the mechanical application of decomposed cattle manure increased 18.46%, followed by mechanical application of granular organic fertilizer increased 17.74%, and the increase of soil urease activity was not obvious when straw was returned to the field. In addition, the soil urease activity reached the highest during the
whole growth period of corn. However, the effects of each treatment in this period were as follows: IV > I > II > III > V.

4.2. Mechanization can improve soil phosphatase activity, especially small increase and the best results can be obtained from the straw treatment

The soil phosphatase activity did not change greatly during the whole corn growing period, but it still increased slightly. The best effect was to increase the soil phosphatase activity by breaking the straw into the field at Tasselling stage, but the overall average value was: I > II > IV > III > V.

4.3. Mechanization was effective on improving soil cellulase activity with II, and the best results can be obtained from the treatment at the stage of Heading.

From the whole growth period, the best effect of improving soil cellulase activity was that the treatment of II, straw returning to the field had an obvious effect on the increase of soil cellulase activity. Soil cellulase activity was the highest in the heading stage, and the effect of straw returning to the field was the best.

4.4. Mechanization was effective on improving soil catalase activity, the best one is II, and III is lower than conventional fertilization. The peak period of activity is in the period of Heading.

The best effect of improving soil catalase activity for the whole corn growth period was that the treatment of II straw returning to the field with the broken application was 26.47% higher than that of conventional chemical fertilizer treatment V, and treatment I and IV were also effective but not as good as II treatment. In addition, the effect of III treatment was the worst or even lower than that of conventional chemical fertilizer treatment. The most active period of catalase appeared in the corn heading stage which had an obvious effect. Except for the treatment of III, all of them have an obvious effect.

4.5. Mechanization remarkably was effective on improving soil sucrase activity.

Both organic fertilizer and straw could significantly increase soil sucrase activity, among which organic fertilizer had a better effect. Compared with the conventional chemical fertilizer treatment, the sucrase activity of mechanically applied decayed cattle manure increased by 40.58%. Based on the analysis above, the increase of soil enzyme activity by various mechanized organic fertilization methods was significantly higher than that of conventional chemical fertilizer only during a corn growth period or the whole corn growth period.

Acknowledgments

This study was funded by Natural Science Foundation of China (31772391, 31301842), National Key Research and Development Plan (2018YFD0201206), the Xing Liao Talents Project and Sheng Jing Talents Project (RC170338), China Scholarship Council Project (CSC 201708210143) and National Peanut Research System (CARS-13- Nutrient Management).

References
[1] Zhou, L.K., (1987) Soil Enzyme [M]. Science Press, Beijing, 1987:116-206
[2] Guan, S.M., (1986) Soil enzymes and their research methods [M]. Agricultural Publishing House, Beijing.
[3] Institute of soil fertilizer, Chinese Academy of agricultural sciences. (1963)Annual scientific research report (N).
[4] Sharpley A N.,( 1985)Phosphorus cycling in unfertilized and fertilized agricultural soils[J].Soil Sci Soc A m J, 49:905-911.
[5] Guan, S.M. et al. (1984) Journal of soil., 1984(4): 68-81.
[6] He, J.,(2011) The relationship between plant growth and soil enzyme[J]., New technology and new products in China., 2011(16):234-235.
[7] Dick RP., Soil enzyme activities as integrative indicators of soil health [A]/Pnkrst C, Doube BM, Gupta VVSR.Biological Indicators of Soil Health[M]. Wallingford, Oxon, UK: CAB Internation, 1997: 121–156

[8] Qian, H.Y et al., (2012) Effects of fertilizer and microbe on soil enzyme activity and microbial quantity in paddy fields [J], Journal of ecological environment., 21(3): 440 – 445

[9] Li, C.H., (2012) Effects of different fertilization patterns on microbial community abundance and enzyme activity in oasis farmland [J], Journal of soil., 49(3): 567–574

[10] Bergstrom, D.M, King, D.J., (1998). The sensitivity of soil enzyme activities to conservation practices [J], Soil Sci Soc Am J., 62:1286-1295