JOURNAL OF PURE AND APPLIED MICROBIOLOGY, May 2014. Vol. **8**(Spl. Edn. 1), p. 631-635

Effect of Biological Corn Straw Fermentation Technology on Soil Nutrition and Enzyme Activity

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(Received: 12 April 2014; accepted: 09 May 2014)

The crop straw could be decomposed safely by using beneficial microorganisms (bacteria). It was quickly decomposed and released nutrients, and then improved soil quality. Different ratio of straw and bacterial was conducted for two years where planted eggplants. The results showed that the bacterial and corn straw used for 120 kg and 60000 kg per hectare (C_2 treatment), and bacterial and corn straw used for 120 kg and 72000 kg per hectare (C_3 treatment) could significantly increase soil available nitrogen, available phosphorus, available potassium and organic carbon content. They increased for 22.93%, 48.95%, 16.37% and 22.93% in the first year, respectively, while increased for 34.48%, 56.79%, 21.62% and 56.79% in the second year, respectively. Soil invertase, urease, neutral phosphatase and catalase activities increased by 8.18%, 14.63%, 31.59% and 14.63% in the first year, respectively, but increased for 29.49%, 19.63%, 40.69% and 32.21% in the second year, respectively. The C_2 treatment had the highest integrative index of soil enzymes activity for 9.93 and 12.89 in the two years, respectively. The best ratio of bacteria and corn straw was between 1:500 and 1:600 which returned corn straw for 60000-72000 kg/hm^2.

Key words: Biological corn straw, Fermentation technology, Soil nutrition, Soil enzyme activity.

Crop straw is a kind of energy substances which is full of carbon. It is also the foundation of remaining and improving soil fertility. Crop straw return into the field is a way of crop straw utilization. There are about 600 million ton (t) crop straw which containing nitrogen (N), phosphorus (P) and potassium (K) more than 3 million t, 700 thousand t and 7 million t as well as micronutrient per year in China, respectively[1-2]. There are about 7 million t crop straw containing wheat straw 1.4 million t and corn straw 4-5 million t per year in Qingdao. There are a lot of nutrients containing in corn straw. For example, there are more than 40% soil organic carbon (SOC), while N, P and K are about 0.62%, 0.25% and 1.44% [3]. In addition, there are secondary nutrients containing in the crop straw such as the calcium, magnesium, iron, sulphur, silicon and so on. The crop straw could adjust soil physicochemical properties and microbial characteristics and improve soil fertility or crop production[4]. There are a lot of crop straw is burned by farmers, and the soil ecosystem is disturbed at the same time[5]. Crop straw utilization in agriculture is supported and play a key role in the agricultural waste utilization. A lot of studies showed that the soil fertility, properties and nutrients could be improved by crop straw returning into the field as well as mitigating environment pollution[6-8]. The

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effect of burning crop straw on the environment could be mitigated by crop straw returning into the field and it is also an important way for organic agriculture[9].

Because the effect of common crop straw returning into the field decomposed slowly, but not significant for the present crops. Thus the corn straw returning into the field with bacteria in different ratios was studied in order to investigate the suitable ratio of corn straw to bacteria for high crop harvest and the changes of soil nutrients and enzyme activities under rapidly decomposition of corn straw.

MATERIALS AND METHODS

Experimental design

The experiment was conducted at Qingdao Academy of Agricultural Science in 2010. The plot was separated by cement for 4 m^2. The treatments were shown in Table 1. There were three repeats for each treatment. The basic properties were as follows: 20.27 g/kg SOC; 98.33 mg/kg available N; 113.28 mg/kg Olsen P; 144.93 mg/kg available K, pH 7.09.

Treatments of Bacteria and Vaccine

The name of commercial product bacteria is Shiming biological bacteria 001 which is the lignin and cellulose decomposition bacteria mainly composed by hay bacillus, thermophilic bacillus and so on. In addition, the name of commercial product vaccine is Shiming vegetable vaccine 002 which is a kind of bacteria controlling the activity of pathogenic microorganism in rhizosphere. The bacteria was mixed bran and water in the ratio of 1:15:13 and composted for 4-5 hours. However, the vaccine was mixed bran and water in the ratio of 1:15:13 but composed for 7-15 days.

Table 1. Treatments of the study

Treatments	Bacteria/corn straw per ha	Bacteria/corn straw per plot	Bacteria/corn straw (by weight)
C_1	120 kg/48000 kg	48 g/19.2 kg	1:400
C_2	120 kg/60000 kg	48 g/24.0 kg	1:500
C_3	120 kg/72000 kg	48 g/28.8 kg	1:600
C_4	120 kg/84000 kg	48 g/33.6 kg	1:700
CF	Conventional fertilization, $N:P_2O_5:K_2O$ (15:15:15), 600 kg per ha, urea 300 kg per ha		
CK	Without fertilizer		

Utilization of corn straw, bacteria and vaccine

The corn straw was returned into the ditching under the planting field and bacteria was put on the surface of corn straw, and then covered with soil and irrigated. The vaccine was put in the pit and mixed with soil then put eggplant into the pit, and then punching a series of holes for airing between two eggplants.

Sampling and analysis

The mixed soil samples were collected after eggplant harvest for each plot. They were sieved at 1 mm and 0.25 mm. The contents of SOC was determined by dichromate oxidation method; available N was analyzed by alkaline hydrolysis method; Olsen P was extracted by $NaHCO_3$ solution and tested by colorimetric method; and available K was extracted by NH_4OAc solution and analyzed by flame photometer[10].

The soil invertase, urease, neutral phosphatase and catalase activities was determined by traditional method[11]. Invertase activity was analyzed by 3, 5-dinitrosalicylic acid (DNS) colorimetric method. It was incubated at 37°C for 24 h and was shown by glucose mg/(g 24h). Urease activity was determined by indophenol colorimetric method which was incubated at 37°C for 24 h and was shown by NH_3-N mg/(g 24h). Neutral phosphatase activity was analyzed by disodium phenyl phosphate colorimetric method which was incubated at 37°C for 2 h and was shown by P_2O_5 mg/(g 2h). Catalase activity was analyzed by permanganimetric method which was incubated at 37°C for 24 h and was shown by mL/(g 20 min). The geometric mean was calculated for the integrative index of enzyme activity as follows [12]:

$$\text{GM ea} = \sqrt[4]{Inv \times Ure \times Nph \times Cat} \quad ...(1)$$

Where Inv, Ure, Nph and Cat represented invertase activity, urease activity, neutral phosphatase activity and catalase activity, respectively.

Statistical analysis

All statistical analysis were carried out using SPSS 17.0, and significance test was differentiated by LSD method ($P < 0.05$).

RESULTS AND DISCUSSION

Effect of Bacteria and Corn Straw on Soil Properties

As shown in Fig. 1, soil available N, Olsen P and available K were increased with more corn straw returning into field, while it is more significant in the second year than the first year. In the first year, the available N increased from 112.60 mg/kg to 146.10 mg/kg, increasing for 33.50 mg/kg and 22.93%. Olsen P increased from 56.06 mg/kg to 109.81 mg/kg, increasing for 53.75 mg/kg and 48.95%. Available K increased from 95.72 mg/kg to 114.46 mg/kg, increasing for 18.74 mg/kg and 16.37%. However, the available N increased from 115.27 mg/kg to 175.93 mg/kg, increasing for 60.66 mg/kg and 34.48% in the second year. Olsen P increased from 50.88 mg/kg to 117.75 mg/kg, increasing for 66.87 mg/kg and 56.79%. Available K increased from 116.53 mg/kg to 148.68 mg/kg, increasing for 32.15 mg/kg and 21.62%. In the first year, the amounts of available N was as follows: $C_2 > C_3 > C_1 > C_4 >$ CF> CK. However, the amounts of Olsen P was as follows: $C_2 > C_3 > C_4 > C_1 >$ CF> CK. The amounts of available K was as follows: $C_2 > C_3 > C_1 > C_4 >$ CF> CK. In the second year, the amounts of available N was as follows: $C_3 > C_2 > C_4 > C_1 >$ CF> CK. The amounts of Olsen P was as follows: $C_2 > C_4 > C_3 > C_1 >$ CF> CK. The amounts of available K was as follows: $C_2 > C_3 > C_4 > C_1 >$ CF> CK. These results indicated that the C_2 and C_3 treatments were suitable for improving soil available nutrients.

The amounts of SOC increased from 18.67 g/kg to 23.19 g/kg, increasing for 4.52 g/kg and 19.49% in the first year (Fig. 2). However, it increased from 20.06 g/kg to 33.87 g/kg, increasing for 13.81 g/kg and 40.77%. The amounts of SOC was as follows: $C_2 > C_3 > C_4 > C_1 >$ CF> CK in the first year, while it was as follows: $C_2 > C_3 > C_4 > C_1 >$ CF> CK in the second year. These results indicated that C_2 treatment is better for increasing SOC than other treatments.

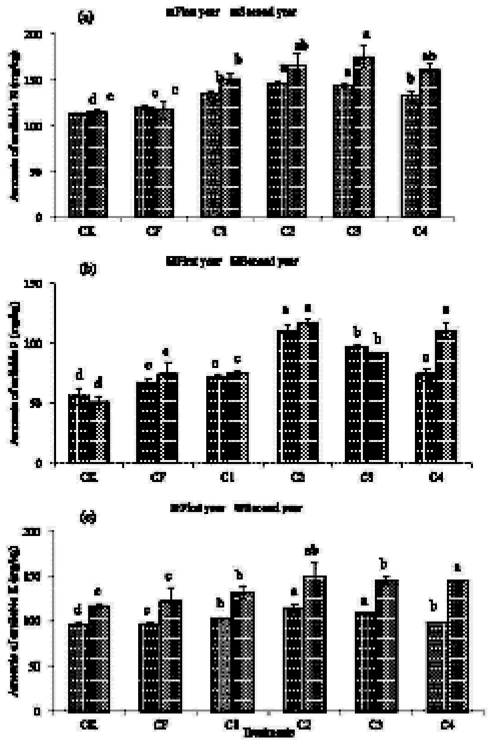

Fig. 1. Effect of corn straw and bacteria on soil nutrients

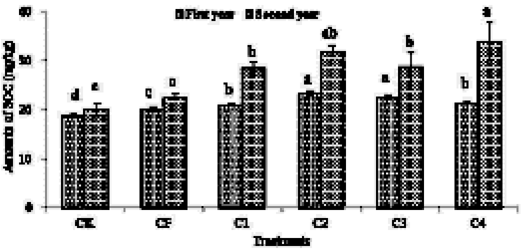

Fig. 2. Effect of corn straw and bacteria on SOC

The strong increase of SOC was in C_2 treatment with crop straw returning into the field for 4000 kg/hm^2 and the bacteria to crop straw ratio was 1:500. The contents of available N, Olsen P, available K and SOC could increase by crop returning into the field with bacteria[13-15].

Effect of Bacteria and Corn Straw on Soil Activities

The soil invertase, urease, neutral phosphatase and catalase activities increased in both first year and second year (Fig. 3). In the first year, soil invertase activities increased from 36.58 mg/(g 24h) to 39.84 mg/(g 24h), increasing for 3.26 mg/(g 24h) and 8.18%. Soil urease activities increased from 1.05 mg/(g 24h) to 1.23 mg/(g 24h),

Table 2. Effect of corn straw and bacteria on soil integrative enzyme activity

Treatments	First year *GM ea*	Second year *GM ea*	First year compared to CK/%	First year compared to CF/%	Second year compared to CK/%	Second year compared to CF/%
CK	8.00	8.91	-	-	-	-
CF	9.14	10.05	14.25	-	12.79	-
C_1	9.16	10.42	14.50	0.22	16.95	3.680
C_2	9.93	12.89	24.13	8.64	44.67	28.26
C_3	9.62	12.15	20.25	5.25	36.36	20.90
C_4	9.42	11.40	17.75	3.06	27.95	13.43

increasing for 0.18 mg/(g 24h) and 14.63%. Soil neutral phosphatase activities increased from 53.02 mg/(g 2h) to 77.51 mg/(g 2h), increasing for 24.49

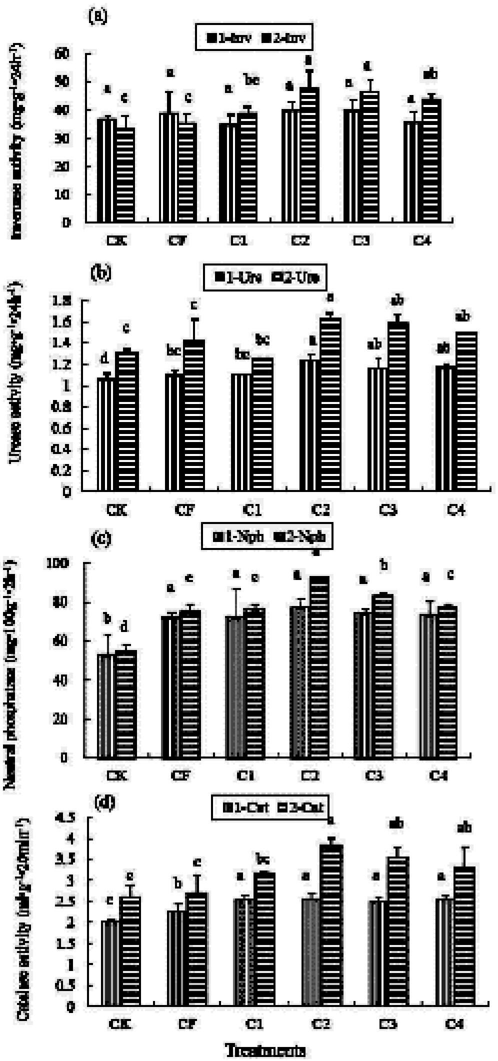

Fig. 3. Effect of corn straw and bacteria on soil enzyme activity

mg/(g 2h) and 31.59%. Soil catalase activities increased from 2.01 mL/(g 20min) to 2.57 mL/(g 20min), increasing for 0.56 mL/(g 20min) and 21.79%. In the second year, soil invertase activities increased from 33.55 mg/(g 24h) to 47.58 mg/(g 24h), increasing for 14.03 mg/(g 24h) and 29.49%. Soil urease activities increased from 1.31 mg/(g 24h) to 1.63 mg/(g 24h), increasing for 0.32 mg/(g 24h) and 19.63%. Soil neutral phosphatase activities increased from 54.87 mg/(g 2h) to 92.53 mg/(g 2h), increasing for 37.65 mg/(g 2h) and 40.69%. Soil catalase activities increased from 2.61 mL/(g 20min) to 3.85 mL/(g 20min), increasing for 1.24 mL/(g 20min) and 32.21%. The enzyme activities was more stronger in C_2 and C_3 treatments than other treatments. The phosphatase and invertase activities could increase with crop straw returning into the field and cultivated deeply or whirling cultivation. Maybe it was related to the increase in SOC with crop straw returning into the soil, especially corn straw for increasing invertase activity[16].

The table 2 was shown that soil integrative index of enzyme activity was high in C_2 treatment. In the first year, it increased for 24.13% and 8.64% in C_2 treatment, compared to CK and CF treatments respectively. In the second year, it increased for 44.67% and 28.26% in C_2 treatment, compared to CK and CF treatments respectively.

ACKNOWLEDGEMENTS

The study was supported by Shandong Modern Agricultural Technology & Industry System (SDAIT-01-022-06) and the Twelfth Five-Years Plan in National Key Technology for Agriculture (three stages of grant No. 2011BAD16B09-03, 2012BAD04B05-03 and

2013BAD07B06-03), and the Excellent Innovation Group of Universities in Shandong Province-Innovation Group of Water Efficiency Utilization for Arid Land Crops.

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