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Application of Straw Biological Reactor in Production of Cherry Tomato

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Abstract

Crop straw is a kind of valuable bio-resource. How to use the resource, other than treating it as a waste, is very important for China and all over the world. Straw biological reactor (SBR) is a technology for returning crop straw into agricultural soils. In this study, effects of SBR with rice straw on the growth environment, fruit yield and economic benefit of cherry tomato were studied in the sheds covered with plastic film. The results showed that SBR treatment increased total N and organic matter contents of the soil by 77.02% and 62.89% respectively, and reduced bulk density and salinity of the soil by 2.63%-24.66% and 34.38% respectively. The atmospheric CO_2 concentrations in the sheds were elevated by 8.05%-279.25%, with an average value of 158.46%, by SBR treatment. It also raised atmospheric temperatures of the shed by 0.2-3.4°C, with an average value of 1.6°C, and increased the soil temperatures by 0.8-6.2°C, with an average value of 3.0°C. As a result, the fruit yield and profit of cherry tomato were raised by 26.22% and 43.71% respectively by the SBR with rice straw. The results indicate that SBR with rice straw can improve the growth environment of cherry tomato, and boost the fruit output and economic benefit effectively.

Keywords

Straw Biological Reactor, Crop Straw, Cherry Tomato, Output, Economic Benefit

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1. Introduction

Crop straw is a kind of bio-resource characterized by large amounts, vary varieties and widespread distribution. It was reported that about 2.9 billion tons of crop straw is produced each year all over the world [1]. China is a traditional agricultural country with huge area of crop land. The output of crop straw in China is more than 700 million tons each year, which occupies at least 24% of the world's production, and cereal crop production produces about 80% of crop straw [2]. Therefore, how to utilize the bio-resource reasonably and efficiently, other than abandoning or burning it as a waste, is a very hard task for China and many other countries in the world.

In some countries, specifically in developing countries, large amount of crop straw is treated simply by field burning [3]. In China, large proportion of crop straw (about 30-40%) is burned and abandoned in open field. About 20% is used as household fuel, about 15% as livestock fodder, about 15% returned to field as organic fertilizer, and only 2% as industrial material [4, 5]. The ways of burning and simple discarding not only waste the bio-resource, but also bring about environmental problems and human health risks.

It was estimated that burning of crop straw, including field and household burning, is an important source of primary and secondary $PM_{2.5}$ emissions in China, which were about 1248, 1485, and 1826 Gg in 2003, 2008, and 2013, respectively [6]. Therefore, burning of crop straw will result in heavy air pollution, and may contribute to acute or potentially long-term

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human health risks. Zhang et al. (2016) reported that crop straw burning accounts for about 8% of over year $PM_{2.5}$ emission in China, and about 26% of $PM_{2.5}$ emission during harvest period of crops [7]. Long et al. (2016) showed that atmospheric $PM_{2.5}$ concentration was increased by 34% by the burning of crop straw in North China [8]. Some researches presented that about 500 road traffic accidents and about 1000 flight delays in China were related to on-site burning of crop straw each year. The diseases of human respiration system also increased in nearby inhabitants during the burning period of crop straw [9, 10].

Crop straw is a kind of very useful bio-resource. It contains high levels of organic matters and many mineral nutrients that are beneficial for the growth and reproduction of crops. It was reported that 33 Mg fresh residues per hectare was found in leek production field, which contains about 99 kg N per hectare. Similarly, up to 50 Mg fresh matter with 200 kg N per hectare was left behind by cabbage production [11]. Return of crop straw into agricultural land is considered as the best strategy for the straw recycling and energy reuse. It can also increase soil organic carbon, nitrogen and many other nutrient elements, improve soil properties, and elevate crop yield and quality [12, 13].

Straw biological reactor (SBR) is a new technology for crop straw return. It has attracted many concerns and researches in China in recent years. Selected microorganisms, activators and purificants are mixed with crop straw in the measurement. The mixture is buried under soil surface (built-in) or placed on soil surface of the filed (built-out). By creating an aerobic environment, the straw will decompose and release organic matters, CO_2, mineral nutrients, and a lot of heat, etc. Therefore, it will be beneficial for crop growth and the resistance to diseases and pests. Some researches presented that SBR can accelerate the decomposition and the matter recycling of crop straw, reduce the use of fertilizers and chemicals, and alleviate the pollution stress on the environment [13, 14]. Therefore, SBR technology can offer a new measure to the better utilization of crop straw.

Up to now, SBR technologies have been used in the production of some vegetables, cereal crops and watermelon successfully. The studies showed that SBR can improve the growth environment, yields, qualities and economic efficiencies of the crops [15-19]. But its application in tomato production has not been reported. In this study, the effects of SBR on the growth environment, fruit output and economic benefit of cherry tomato were investigated in shed planting.

2. Materials and Methods

2.1. Experimental Site and Plant Materials

The study was carried out in Changzhou, Jiangsu Province, China (30°41′ N, 119°50′ E). The plant materials were cherry tomato (*Lycopersicon esculentum* var. cerasiforme) and rice straw.

2.2. Experimental Design

The cherry tomato cultivation and the experiments were arranged in six arched sheds with transparent plastic roofs, each with a land area of 270 m^2 (45 m × 6 m). SBR treatment with rice straw was arranged in three sheds (1500 kg rice straw for each shed, dry weight). Three sheds with no SBR treatment served as the control. Built-in SBR technology (rice straw was buried into the soil at a depth of 15 cm under soil surface) was used in this research [18].

2.3. Analytical Methods

The soil for this study was measured for the following properties: bulk density with cutting ring method [20], total N contents with Kjeldahl method [21], organic matter contents with sequential extraction method [22], and salinity with water extraction method [23]. Atmospheric CO_2 concentrations in the sheds were measured with an Infrared Carbon Dioxide Detector (QGS-10, China) [24]. Atmospheric temperatures at 1.5 m above soil surface and soil temperatures at the depth of 20 cm under soil surface were measured with thermometers.

3. Results and Discussion

3.1. Effects of Straw Biological Reactor on Soil Properties

Effects of SBR treatment on bulk densities, contents of total N and organic matter, and salinities of the soils are presented in Table 1. The soil bulk densities of SBR treatment were lower than the control. The decreasing effects differed with soil layers, and they are in the order: 20-30 cm layer > 10-20 cm layer > 0-10 cm layer. Compared to the control, SBR treatment increased total N and organic matter contents of the soils greatly and significantly ($P < 0.01$), but decreased soil salinities largely and significantly ($P < 0.01$). Therefore, SBR treatment could improve soil properties, which would be beneficial for crop growth and yield formation. Higher contents of total N, total P, available K and soluble organic carbon, and lower bulk densities in the soils with the retention of crop residues were also reported in other’s study [25].

Table 1. Effects of Straw Biological Reactor on Soil Properties.

	Bulk Density (g/cm[3])			Total N (g/kg)	Organic Matter (g/kg)	Salinity (g/kg)
	0−10 cm	10−20 cm	20−30 cm			
Control	1.14	1.26	1.46	1.61	32.63	0.64
Treatment	1.11	1.18	1.10	2.85	53.15	0.42
±% [a]	-2.63	-6.35*	-24.66**	77.02**	62.89**	-34.38**

[a] Relative changes as compared to the control.
*, ** Significant difference between the control and SBR treatment at $P < 0.05$, $P < 0.01$, respectively

3.2. Effects of Straw Biological Reactor on Atmospheric CO_2 Concentration, Atmospheric and Soil Temperature

The differences between SBR treatment and the control in shed atmospheric CO_2 concentrations are illustrated in Figure 1.

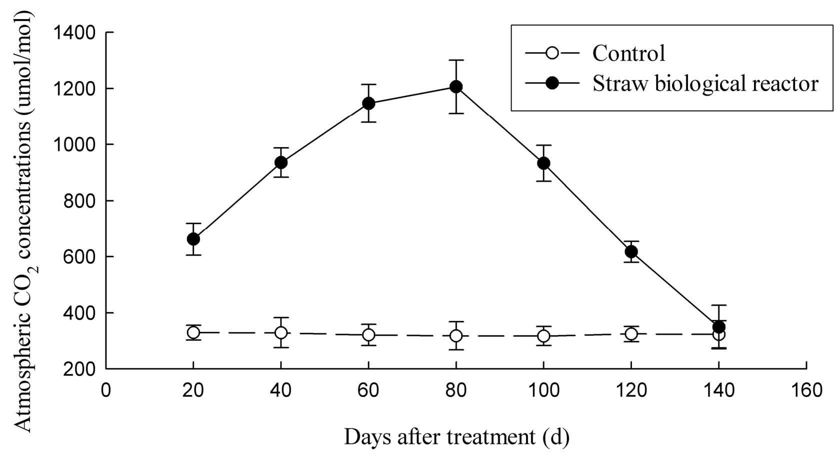

Figure 1. Effects of Straw Biological Reactor on Shed Atmospheric CO_2 Concentrations.

Compared to the control, atmospheric CO_2 concentrations in the sheds were greatly elevated by SBR treatment. During the experiment, the average CO_2 concentration of the control was 323.3 μmol/mol, but the average CO_2 concentration of SBR treatment was as high as 835.6 μmol/mol. The increasing rates ranged from 8.05% to 279.25%, with an average value of 158.46%. Within 80 days after the treatments, the differences between SBR treatment and the control increased with the days of SBR treatment. After 80 days, the differences decreased with the days of SBR treatment. At the 140th day after SBR treatment, the difference was small and insignificant ($P > 0.05$).

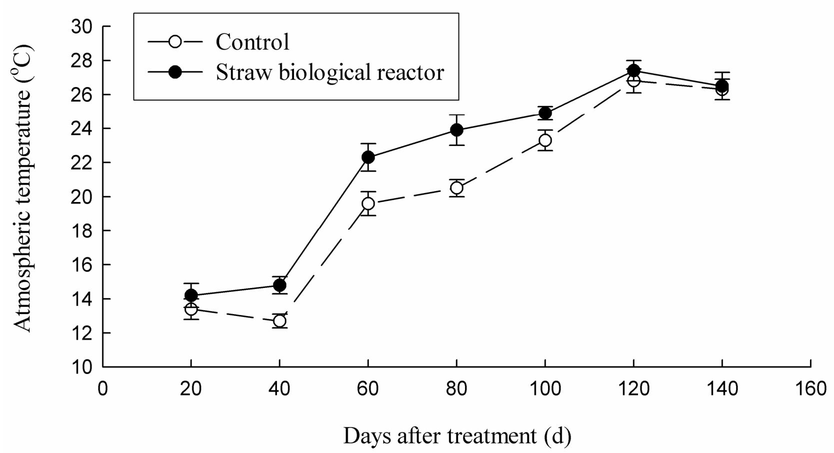

Figure 2. Effects of Straw Biological Reactor on Shed Atmospheric Temperatures.

The atmospheric temperatures in the sheds were also raised obviously by the SBR treatment (Figure 2), but the effects were not as high as on CO_2 concentrations. The increasing magnitudes were 0.2-3.4°C, with an average value of 1.6°C. The increasing rates ranged from 0.76% to 16.59%, with an average value of 7.99%. The differences between SBR treatment and the control in shed atmospheric temperatures were significant (P < 0.05 or 0.01) at 40th, 60th, 80th and 100th day after SBR treatment, but insignificant (P > 0.05) at 20th, 120th and 140th day after the treatment.

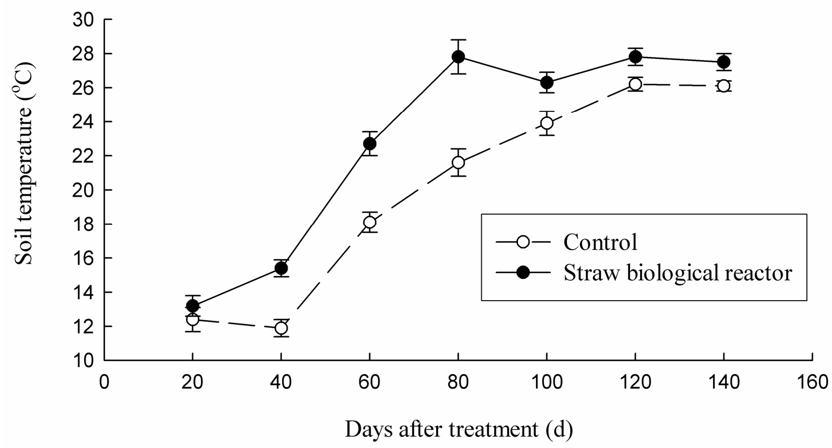

Figure 3. Effects of Straw Biological Reactor on Shed Soil Temperatures.

Effects of SBR treatment on soil temperatures are presented in Figure 3. The soil temperatures were also increased by SBR treatment significantly. The increasing magnitudes were 0.8-6.2°C, with an average value of 3.0°C. The increasing rates ranged from 5.36% to 29.41%, with an average value of 14.62%. The differences between SBR treatment and the control in soil temperatures were significant (P < 0.05 or 0.01) except at 20th day after the SBR treatment.

3.3. Effects of Straw Biological Reactor on Fruit Yield and Economic Benefit of Cherry Tomato

It was reported that straw retention with liming improved N uptake and increased rice yield by 11.6% [26]. But some short-term researches presented that straw retention did not raise or even reduced rice yield because of high C/N ratio of straw and microbial N immobilization [27, 28]. Our present study shows that SBR treatment can increase fruit yield and economic benefit of cherry tomato largely (Table 2). Although single fruit weight was raised small and insignificantly (P > 0.05), fruit weight per plant and fruit yield per hectare were increased highly and significantly (P < 0.01). Because of better appearance and taste of the fruit, the sale price was about 10% higher for SBR treatment than for the control. As a result, the fruit output value was greatly elevated by the SBR treatment. The profit for SBR treatment was also more than 40% higher than the control, although the production cost was about 30% higher for SBR treatment than for the control.

Table 2. Effects of straw biological reactor on fruit output and economic benefit of cherry tomato.

	Single Fruit Weight (g)	Fruit Weight Per Plant (kg/plant)	Fruit Yield (kg/ha)	Sale Price (RMB yuan/kg)	Output Value (RMB yuan/ha)	Cost (RMB yuan/ha)	Profit (RMB yuan/ha)
Control	16.8	1.16	56475	16.2	903600	122475	781125
Treatment	17.5	1.43	71280	17.8	1283040	160500	1122540
±%	4.17	23.28**	26.22**	9.88*	41.99**	31.05**	43.71**

*, ** Significant difference between the control and SBR treatment at P < 0.05, P < 0.01, respectively

4. Conclusions

The soil properties were significantly ameliorated by SBR treatment. Bulk densities were reduced by 2.63%-24.66%, total N was raised by 77.02%, organic matter content was increased by 62.89%, and the soil salinity was decreased by 34.38%. The growth environment of cherry tomato was also improved greatly by the SBR treatment. The atmospheric CO_2 concentrations in the sheds were elevated by 8.05%-279.25%, with an average value of 158.46%. The atmospheric temperatures were raised by 0.2-3.4°C, with an average value of 1.6°C. The soil temperatures were increased by 0.8-6.2°C, with an average value of 3.0°C. As a result, fruit weight per plant, fruit yield per hectare, and fruit output value and profit were all increased largely.

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