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Research Article

Improvement Effect of Vermicompost on Continuous Cropping Obstacle Soil of Cherry Tomato (*Lycopersicon esculentum* Mill.)

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Abstract

The continuous cropping obstacles of cherry tomato are serious in Lingshui county, Hainan Province, China. It is imperative to soil improvement. Vermicompost is one of the most ideal soil amendment. The field experiments were conducted to explore the improvement effect of vermicompost on typical continuous cropping obstacle soil from the viewpoints of yield and quality of cherry tomato, soil chemical properties and micro-ecological environment. After applying vermicompost in cropping obstacles soil of cherry tomato, the yield of cherry tomato was increased by 50.9%, and the contents of soluble sugar and vitamin C were increased by 10.9% to 26.7% and 4.6% to 6.2%, respectively. Those of soil organic matter, available Ca and Mg were increased by 10.8%, 92% and 48.9%, respectively. Those of trace elements Mn, Zn and B were increased by 24%, 16.5% and 41.9%, respectively. The activities of soil urease, acid phosphatase and catalase were enhanced by 41.3%, 20.9% and 24.2%, respectively. Furthermore, the composition of soil microbial community was obviously optimized, with the ratio of bacteria to fungi and the relative abundance of soil beneficial microorganisms being significantly increased after applying vermicompost. In conclusion, the yield of cherry tomato was significantly increased, and the quality of cherry tomato, soil chemical properties and micro-ecological environment were obviously improved after applying vermicompost.

Keywords

Vermicompost, Cherry Tomato, Continuous Cropping Obstacles, Soil Improvement, Soil Chemical Properties, Micro-ecological Environment

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1. Introduction

Cherry tomato (*Lycopersicon esculentum* Mill.) has been listed as one of the "Four fruits" prioritized for promotion by the Food and Agriculture Organization of the United Nations due to its rich nutritional value. And the cherry tomato industry is the economic pillar industry of Lingshui County, Hainan province, China because of its unique flavor. However, the habitat environment is deteriorating due to the continuous cultivation of single mode for a long time. The yield and quality of cherry tomato decreased significantly, and even some plots failed to harvest. Therefore, it is imperative to soil improvement.

The existing soil improvement techniques of continuous cropping obstacles mainly include crop rotation and intercropping, resistant cultivar cultivation, biological control and rational fertilization [1-5]. However, it is difficult to implement crop rotation in Lingshui county due to intensive planting and limited land resources. The cultivation techniques for resistant varieties are also difficult to achieve because it is difficult to breed the varieties that are resistant to multiple soil-borne diseases simultaneously. In addition, farmers in Lingshui cannot apply fertilizer properly because they blindly pursue short-term benefits. They often rely too much on chemical fertilizers instead of organic fertilizers. It is worth paying attention to the application of organic fertilizer to improve the soil with continuous cropping obstacles. Vermicompost is known as the king of organic fertilizeris and is one of the most promising soil amendments [6]. It is rich in organic matter, microorganisms and growth factors, which can better improve the soil ecological environment and achieve the effect of improving soil fertility and disease resistance [7]. Vermicompost can not only promote crop growth, increase crop yield, and improve crop quality [8-10], but also inhibit the occurrence of soil-borne diseases [11-13]. In this study, field experiments were conducted to explore the improvement effect of vermicompost on continuous cropping obstacle soil from the aspects of soil chemical properties, soil micro-ecological environment, the yield and quality of cherry tomato, aiming to provide theoretical basis for effectually alleviating continuous cropping obstacles of cherry tomato.

2. Materials and Methods

2.1. Experiment Design

The cherry tomato field continuously cultivated for 10 years was selected as the experimental plot in Guangpo Town, Lingshui County, Hainan Province, China (110°04′27.5″E, 18°33′23.9″N). The soil type of experiment land was paddy soil developed from laterite, which texture is sandy loam. Two different treatments were set up as base fertilizer with single application of chemical fertilizer (CK) and single application of vermicompost (T), with each treatment having three replications. The application amounts of vermicompost and chemical fertilizer were 30000 kg/ha and 1200 kg/ha, respectively. The type and frequency of top dressing were consistent in the two treatments, and the other management modes in two treatments were also same. The basic chemical properties of tested vermicompost and obstacle soil were shown in Table 1.

Table 1. *Basic chemical properties of tested vermicompost and soil.*

Chemical index	Vermicompost	Obstacle soil
pH	7.13	5.68
OM (g/kg)	230	13.5
AP (mg/kg)	151	76.7
AN (mg/kg)	630	74.76
AK (g/kg)	7.76	0.14
Available Ca (g/kg)	6.04	1.91
Available Mg (g/kg)	2.08	0.13
Available Fe (mg/kg)	192	276
Available Zn (mg/kg)	27.1	7.33
Available B (mg/kg)	24.1	0.47

2.2. Soil Sample Collection

The 0-20-cm tillage layer soils were taken during harvest time of cherry tomato in mid-April 2023. Soil sampling methods were referred to those described by Deng et al [14]. A total of 6 soil samples were obtained. Each soil sample was divided into two parts after passing through a 2mm sieve. the first part was air-dried and then used for the determination of soil chemical properties and enzyme activities. The second part was stored at -80 ℃ and then used for the analyses of microbial community composition and diversity.

2.3. Analysis of Soil Chemical Properties and Enzyme Activities

Soil pH, organic matter (OM), alkali-hydrolyzed nitrogen (AN), available phosphorus (AP), and available potassium (AK), available Ca, available Mg, available Mn, available Zn, available Cu and available B were measured using routine methods described by Bao [15]. The activities of soil urease, catalase and acid phosphatase were determined by kit (Suzhou Keming Biotechnology Co., LTD.)

2.4. Soil DNA Extraction, PCR Amplification, and Sequencing

Total soil DNA was extracted using the Power Soil DNA Separation kit (MO BIO Laboratories, Carlsbad, CA, United States). The PCR was conducted under the conditions described by Wu et al. [16]. The libraries were build and sequenced by Biomarker Biotechnology Co., Ltd. (Beijing, China) using the Illumina Novaseq 6000 sequencing system (Illumina, Santiago, CA, United States).

QIIME 1.8.0 was used to splice and filter the high-throughput original sequences. UCHIME v4.2 was used to identify and remove chimeras to obtain optimized sequences. Then, UPARSE (USEARCH, version 10.0) was used to cluster the optimized sequences at the 97% similarity level to obtain operational taxonomic units (OTUs). The alpha diversity indices, including Chao1 and Shannon indices were calculated using Mothur version v.1.30 on the BMK-Cloud. Non-metric multidimensional scaling (NMDS) based on Bray–Curtis dissimilarity was used to examine the beta diversity (A stress value of > 0.2 indicates that this method is not appropriate).

2.5. Analysis of Yield and Quality of Cherry Tomato

Six ridges were selected for each treatment as six replicates, and five plants were randomly selected from each ridge to be marked. The number of ripe fruits of the marked plants was counted and weighed each time, and the average number of fruits per plant and weight per fruit were calculated. The yield was calculated according to the number of fruit per plant, the weight per fruit and the number of planted plants per hectare. The formula was as follows: Yield (kg/ha) = weight per fruit (kg)×fruit number per plant× number of planted plants per ha. After cherry tomato fruit ripening, the fruits with the same growth and development status in each treatment were selected to determine the contents of soluble sugar and vitamin C. The contents of soluble sugar and vitamin C were determined by anthrone colorimetry and 2, 6-dichlorophenol indophenol sodium titration, respectively.

2.6. Statistical Analyses

Replicate data were expressed as mean ± standard deviation (SD). The SPSS v.17.0 software package (IBM Corp., Armonk, NY, United States) was used to perform the calculations and compare the treatment means for each experiment. Significant differences between the means were assessed using Duncan's tests. Statistical significance was set at $p \leq 0.05$.

3. Results

3.1. Effects of Vermicompost on the Yield and Quality of Cherry Tomato

The yield of cherry tomato fruit was significantly increased after applying vermicompost in cropping obstacles soil. The total yield of 6 batches of cherry tomato fruits in T treatment and CK were 26259.4 kg/ ha and 17398.8 kg/ ha, respectively. The yield in T treatment was increased by 50.9% compared with CK (Figure 1). Cherry tomato fruits can be harvested once every 7 to 10 days during the fruiting period, and about 10 batches can be picked during the whole harvest period. The estimated yield of T treatment and CK was 43763kg/ ha and 28996 kg/ ha. As shown in Figure 2, the soluble sugar content of cherry tomato fruit was significantly increased by 10.9% to 26.7%, and vitamin C content was also significantly increased by 4.6% to 6.2% after applying vermicompost in cropping obstacles soil.

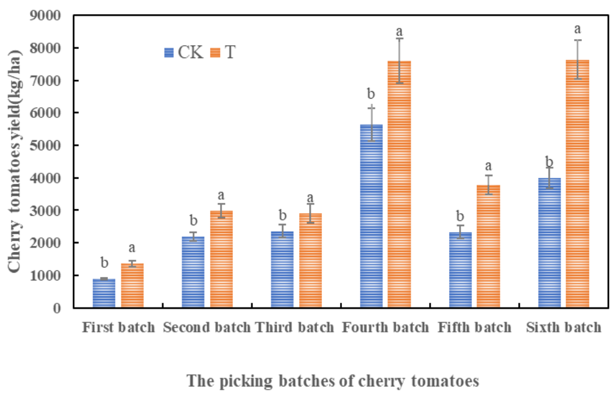

Figure 1. *Changes of cherry tomatoes yield after applying vermicompost in continuous cropping obstacle soil. Different letters indicate significant differences between different treatments ($p \leq 0.05$).*

3.2. Effects of Vermicompost on the Soil Chemical Properties and Enzyme Activities

The chemical properties were obviously improved after applying vermicompost in cropping obstacles soil Table 2). The soil pH value was increased by 0.37 units, and the OM content was increased by 10.8%. The contents of medium elements such as Ca and Mg were increased by 92% and 48.9%, respectively. And the contents of trace elements such as Mn, Zn and B were increased by 24%, 16.5% and 41.9%, respectively. The results also showed that the enzyme activities were significantly enhanced after applying vermicompost in cropping obstacles soil. And the activities of urease, acid phosphatase and catalase were enhanced by 41.3%, 20.9%, and 24.2% respectively.

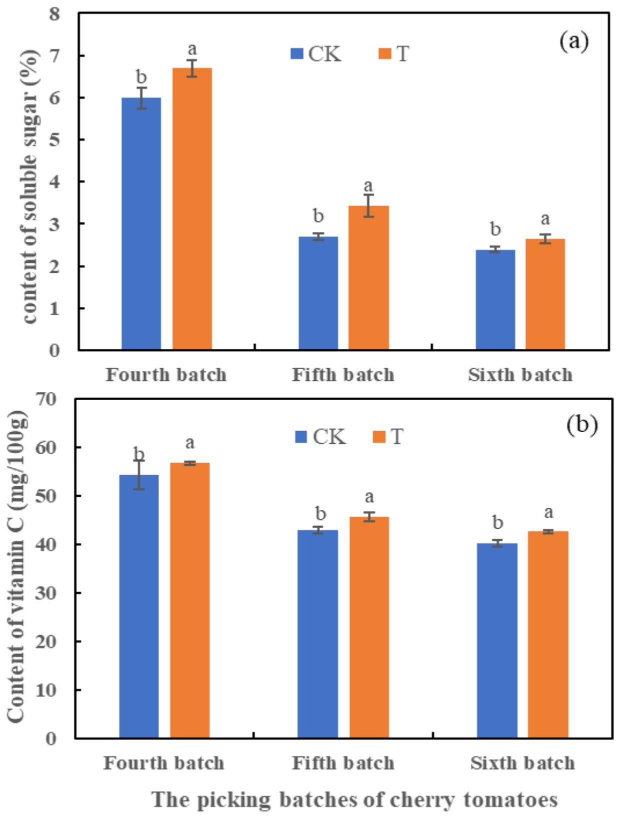

Figure 2. *Changes of cherry tomatoes quality after applying vermicompost in continuous cropping obstacle soil (a) soluble sugars; (b) Vitamin c. Different letters indicate significant differences between different treatments (p≤0.05).*

Table 2. *Changes of soil chemical properties and enzyme activities after applying vermicompost in continuous cropping obstacle soil.*

Detection indicators	CK	T
pH	5.27±0.21 b	5.64±0.18 a
OM (g/kg)	16.1±1.77 b	17.8±1.59 a
AP (mg/kg)	108±9.86 a	95.5±8.98 b
AN (mg/kg)	83.6±7.23 a	81.4±8.61 a
AK (g/kg)	151±14.87 a	125±11.79 b
Available Ca (g/kg)	896±79.6 b	1720±162 a
Available Mg (g/kg)	130±11.5 b	193±17.5 a
Available Mn (mg/kg)	26.2±1.89 b	31.8±2.32 a
Available Zn (mg/kg)	3.29±0.29 b	3.83±0.31 a
Available B (mg/kg)	0.19±0.02 b	0.26±0.02 a
Urease (μg/d/g air dried soil)	84.5±5.2 b	119±11.5 a
Acid phosphatase (nmol/h/g air dried soil)	827±37.7 b	999±45.0 a
Catalase (μmol/h/g air dried soil)	158±27.5 b	197±32.0 a

3.3. Effects of Vermicompost on Soil Microbe

The composition of soil bacteria and fungi community was basically the same between T treatment and CK, but the relative abundance of some microorganisms was significantly different. At the phylum classification level, Proteobacteria and Ascomycota had the highest relative abundance in both treatments, followed by Chloroflexi and Basidiomycota (Figure 3). After applying vermicompost, the relative abundance of Chloroflexi, Acidobacteria, Bacteroidetes and Actinobacteria were increased by 20.0%, 9.3%, 10.3% and 15.7%, respectively. And the relative abundance of Basidiomycota and Mortierellomycota also increased significantly, with an increase rate of 57.9% and 81.4%, respectively. The NMDS analysis results (Figure 4) showed that the soil samples of CK1, CK2 and CK3 were relatively close and distributed in the same coordinate axis. The soil samples of T1, T2 and T3 were relatively close and distributed in the other coordinate axis, indicating that the soil microbial community structure changed significantly after applying vermicompost in cropping obstacles soil. The Chao1 index and Shannon index of soil bacteria increased by 21.3% and 7.84%, while the fungal Chao1 index and Shannon index decreased by 10.7% and 12.7% respectively after applying vermicompost in cropping obstacles soil (Figure 5).

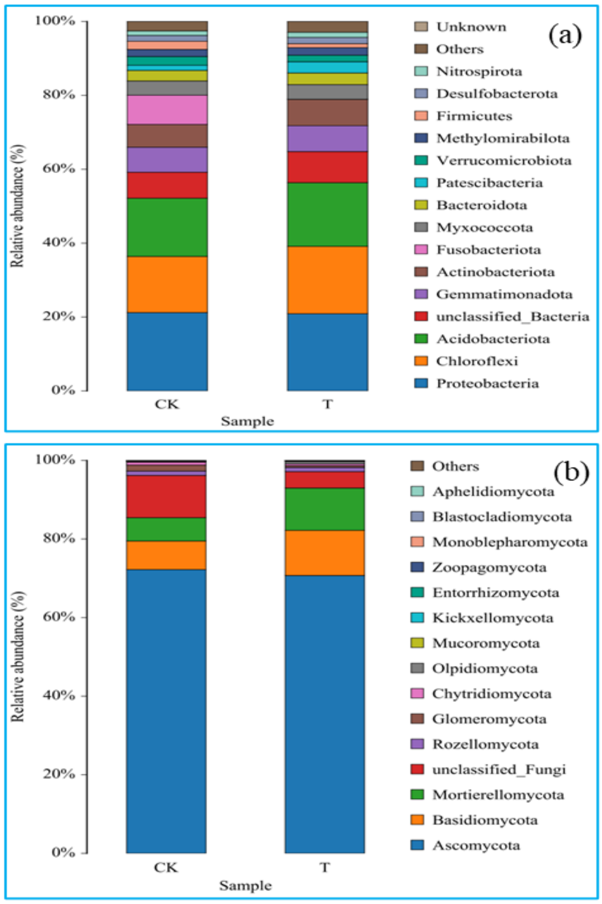

Figure 3. *Changes of soil microbial community composition after soil improvement (a) Bacteria; (b) Fungi.*

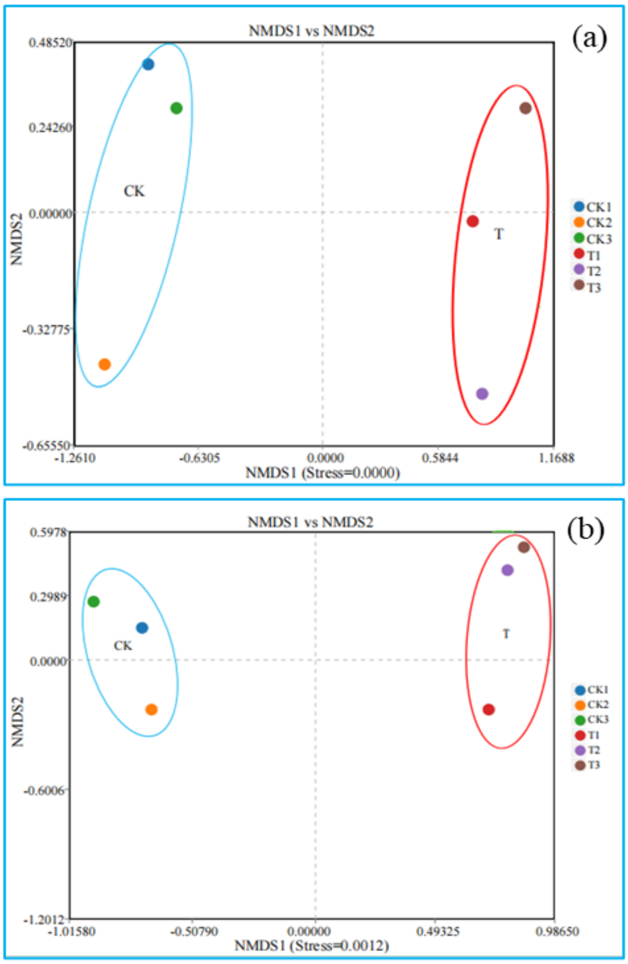

Figure 4. *Changes of soil microbial community structure after soil improvement (a) Bacteria; (b) Fungi.*

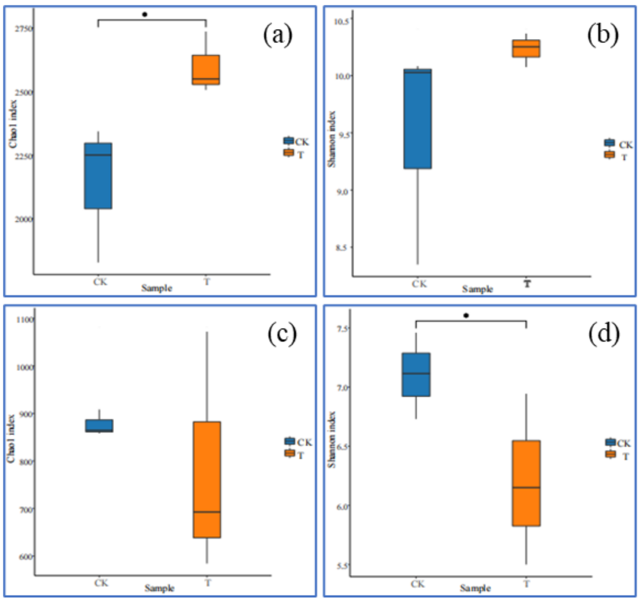

Figure 5. *Changes of soil microbial diversity index after soil improvement (a)-(b) Bacteria; (c)-(d) Fungi.*

4. Discussion

The yield and quality of cherry tomato were significantly improved after applying vermicompost in the soil with continuous cropping obstacles, indicating vermicompost has comprehensive nutrients and can provide sufficient nutrition and promote the growth of cherry tomato plants [6]. Vermicompost significantly increased the pH value, available nutrient contents, and enzyme activities of the acid soil with continuous cropping obstacles, indicating it has a variety of functions [17]. The results also showed that the alpha diversity index of bacteria was significantly increased, while that of fungi was significantly decreased after applying vermicompost in the continuous cropping obstacle soil, indicating vermicompost improves soil microecological balance by optimizing soil microbial community structure [18, 19].

5. Conclusion

The improvement effect of vermicompost on the continuous cropping obstacle soil of cherry tomato was significant. And the yield of cherry tomato was significantly increased, the quality of cherry tomato, soil chemical characteristics and microecological environment were obviously improved after applying vermicompost in the soil with continuous cropping obstacles. However, previous studies had shown that the alleviating effect of vermicompost on the continuous cropping obstacals was not enhanced by more application, and the optimum additional amount varied with different crop species. Therefore, it is recommended to strengthen the research on the optimal application amount of vermicompost in the continuous cropping obstacle soil of cherry tomato.

Abbreviations

OM	Organic Matter
AP	Available Phosphorus
AN	Alkali-Hydrolyzed Nitrogen
AK	Available Potassium

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Author Contributions

Xiao Deng: Writing-original-draft, Funding acquisition
Chunyuan Wu: Writing – review & editing
Yi Li: Formal Analysis
Hua Dong Tan: Software

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Xiao Deng is an associate researcher at Environmental and Plant Protection Institute, Chinese Academy of Tropical Agricultural Sciences. She completed her PhD in Agronomy from Hainan University in 2012, and her Master of Agronomy from Hunan Agricultural University in 2003. Her current research interests include agricultural environmental assessment and soil improvement. She has participated in multiple national research projects and published several scientific and technical papers in international journals in recent years.