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Enhancing Plant Residue Composting using *Bacillus* sp. in Semi-Arid Regions

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Abstract: This study dealt with the effects of water content and microorganisms added on fermentation process including reduction of greenhouse gas emission. Experimental composting was conducted in the glass house. Initial water content was controlled at 60% as standard water content for Run A and B, and then *Bacillus* sp. was added for Run B but not for Run A. Also initial water content was controlled at 45% as lower one for Run C and D, and then *Bacillus* sp. was added for Run D but not for Run C. Based on the results of experimental composting, carbon-nitrogen ratio in compost with *Bacillus* sp. became 88% or 84% of the initial stage of composting, although the ratio in compost without *Bacillus* sp. was only 94% or 96%, respectively. There was a significant difference in carbon-nitrogen ratio at 99% confidence interval between compost with *Bacillus* sp. and that without *Bacillus* sp. under lower water content at 45%. Also, in the experimental results of gas analysis, there was no significant difference in gas emissions of carbon dioxide or methane gas between composting with *Bacillus* sp. and that without *Bacillus* sp. under either water content. However, methane gas emission from composting under lower water content at 45% was significantly lower than that under standard water content at 60%.

Keywords: *Bacillus* sp., Carbon dioxide, Compost, Methane, Plant residue

1. Introduction

Frequent drought and low fertility of soils are the fundamental agricultural problems in semi-arid regions of Asia. Composting has been an effective way in agriculture to improve land productivity. The composting of tree branches or leaves pruned is a process of promoting the fermentation by microorganisms. Although water content in materials is one of the necessary requirements for fermentation process by microorganisms, it is difficult to supply enough water for fermentation during dry season in semi-arid regions of Asia. Also, greenhouse gas emission such as carbon dioxide or methane gas occurs during composting. There were some studies concerning greenhouse gas emission during composting and reported suitable strategies to overcome the problems. Hellebrand (1998) suggested that about 80% of initial carbon mass (initial mass of the compost heap was 14,800 kg with carbon content of 4,300 kg) was transformed by microorganisms into carbon dioxide during composting of grass and green waste. Also methane was produced 1.5-2.0% of initial one. Also, Shiraishi *et al*. (2006) reported that the initial water content should be controlled at 55% to reduce greenhouse gas such as nitrous oxide and methane. Kuroda (2002) suggested the addition of *Bacillus* sp. was effective to reduce malodor emission during composting. Therefore, research interests have been focused on the changes in fermentation or greenhouse gas emission with water content or microorganism addition during composting.

So, the objectives of this study are to investigate the effects of water content and microorganism addition on the fermentation process including the reduction of greenhouse gas emission.

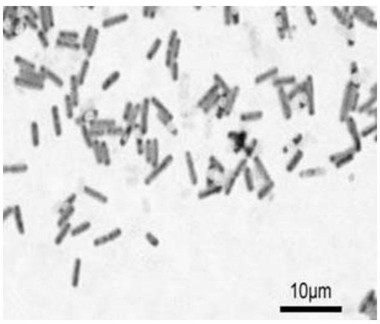

Fig. 1. ***Bacillus*** **sp.**

2. Materials and Methods

Experimental composting was conducted from 15 October to 14 November 2007 in the glass house. The composting of tree branches or leaves pruned was done by the heaping method generally used as a method of the composting pruned one. The plastic box of 50 cm long, 40 cm wide and 40 cm high was used as a compost box and the temperature was not controlled. Initial water content was controlled by adding water at 60% as standard

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water content for Run A and B, and then *Bacillus* sp. (**Fig. 1**) was added for Run B but not for Run A.

Also initial water content was controlled at 45% as lower water content for Run C and D, and then *Bacillus* sp. was added for Run D but not for Run C. *Bacillus* sp. was isolated from the matured compost of tree branches or leaves pruned. The amounts of Bacillus sp. added to compost were 1.2 × (10^8-10^9) cfu/g (dry mass). The amounts of *Bacillus* sp. were measured by the dilution plate counting method.

Gases produced during composting and composting materials were sampled and analyzed at certain interval. Carbon dioxide and methane gas concentration were analyzed from sampled gases at every 2 days by vacuum method using gas detection tube. Also water content, carbon and nitrogen concentration from sampled composting materials were measured at every 10 days. Water content was measured by the oven dry method, total carbon by ignition loss method, total nitrogen by absorption spectrophotometry after decomposition with potassium peroxodisulphate.

3. Results and Discussion

3.1. Carbon-nitrogen ratio

The results of changing carbon-nitrogen ratio during experimental composting were summarized in **Figures 2** and **3**. In the experimental composting, carbon-nitrogen ratio decreased gradually for all Runs. It was considered the fermentation during composting has advanced. But there was no significant difference in changing carbon-nitrogen ratio between decomposed with *Bacillus* sp. and without *Bacillus* sp. under standard water content at 60%.

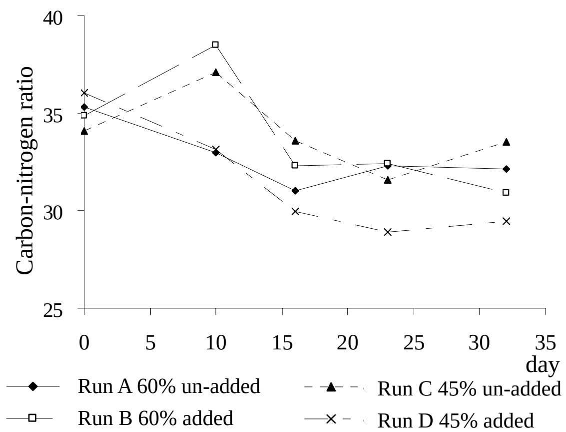

Fig. 2. Changes in carbon-nitrogen ratio during experimental composting.

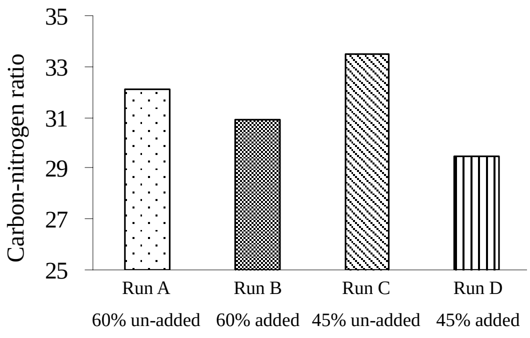

Fig. 3. Carbon-nitrogen ratio in the period of experimental composting.

However, under lower water content at 45% such as Run C and D, the changes in carbon-nitrogen ratio of decomposed with *Bacillus* sp. of Run D tended to be lower than that without *Bacillus* sp. of Run C. Also, in the results of carbon-nitrogen ratio of experimental composting, there was a significant difference at 99% confidence interval in carbon-nitrogen ratio in Run C and that in Run D. It means the addition of *Bacillus* sp. was effective to enhance the composting of tree branches or leaves pruned only under lower water content at 45%. It was considered that many kinds of microorganisms worked actively under standard water content at 60%, but not under lower water content at 45%. So, it was considered that addition of *Bacillus* sp. was clearly effective for composting under lower water content at 45%.

3.2. Gas concentration

According to the results of gas analysis, there was a tendency for the emission of carbon dioxide to be remarkably high at the initial stage of composting process, but gradually decreased with the time. But there was no significant difference in carbon dioxide emission among Run A to D as shown in **Figure 4**. Additionally, although there was a tendency for methane gas emission from Run B and D with *Bacillus* sp. to be lower than that from Run A and C without *Bacillus* sp., there was no significant difference in methane gas emission between composting with *Bacillus* sp. and that without *Bacillus* sp.. It means the addition of *Bacillus* sp. was not effective to reduce the emissions of carbon dioxide or methane gas during composting.

However, methane gas emission from composting under lower water content at 45% such as Run C and D were significantly lower than that under standard water content at 60% such as Run A and B as shown in **Figure 5**. Shiraishi *et al*. (2006) reported the methane gas emission occurred mainly in the early phase of beef cattle manure composting, and could be reduced by lowering the initial water content. Also, Osada *et al*. (1997) suggested that it was possible to reduce the emission of methane gas and nitrous oxide through maintaining the aerobic condition. On the basis of these reports, it was considered the emission of methane gas was due to insufficient aerobic condition. In this study, the emission of methane gas from standard water content at 60% such as Run A and B were higher than that from lower water content at 45% such as Run C and D. So, it was considered that standard water content at 60% of insufficient aerobic condition in composting process resulted higher emission of methane gas.

Accordingly, it was concluded that in composting process of tree branches or leaves pruned, it is important to maintain in aerobic conditions to reduce the emission of methane gas.

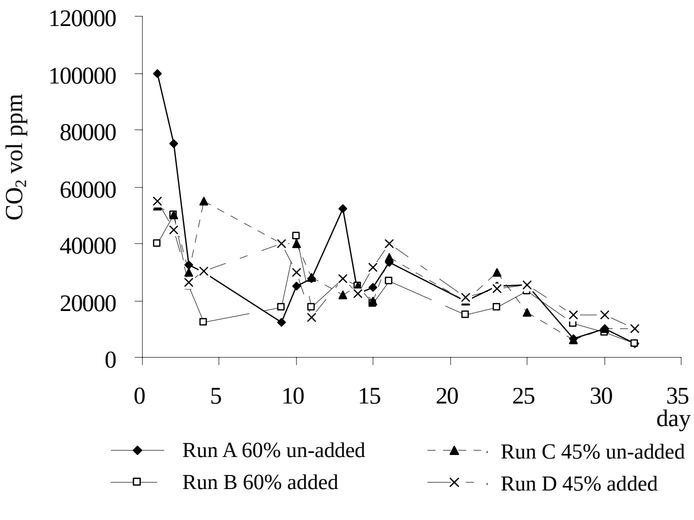

Fig. 4. Changes in carbon dioxide concentration during experimental composting.

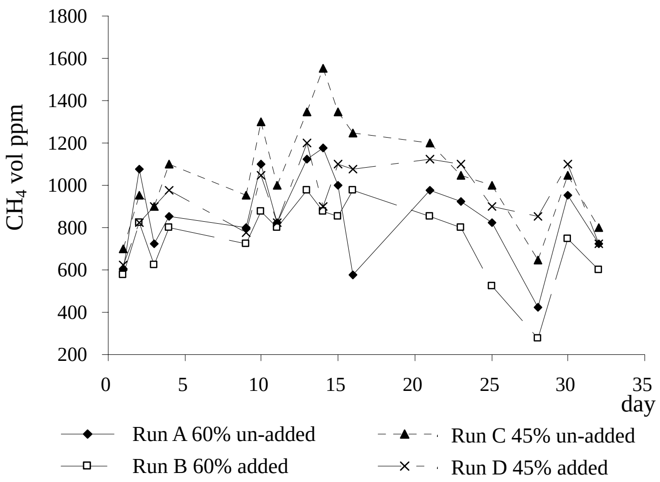

Fig. 5. Changes in methane concentration during experimental composting.

4. Conclusions

This study dealt with the effects of water content or microorganisms added on fermentation process including reduction of greenhouse gas emission. The difference in carbon-nitrogen ratio in compost between fermented at 60% water content as standard one and fermented at 45% water content as lower one was not apparent; however carbon-nitrogen ratio in compost with *Bacillus* sp. was lower than the ratio in compost without *Bacillus* sp. under lower water content at 45%. It means the addition of *Bacillus* sp. was effective for composting especially under lower water content at 45%.

In the experimental results of gas analysis, there was no significant difference in gas emissions of carbon dioxide or methane gas between composting with *Bacillus* sp. and that without *Bacillus* sp. under either water content. However, methane gas emission from composting under lower water content at 45% was significantly lower than that under standard water content at 60%.

So, it was concluded the addition of *Bacillus* sp. was effective for composting especially under lower water content at 45%, but for decreasing the emission of methane gas in composting process, the important was to maintain aerobic conditions of compost under lower water content at 45%.

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