Study on watering patterns to produce non-reversible compost piles

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Abstract. This research investigates different watering patterns in non-reversible compost production processes to compare their effectiveness in facilitating compost decomposition. The controlled factors include composting duration, watering duration, composting materials, compost pile size, and water quantity. Four watering patterns were conducted: 1) manual watering, 2) drip irrigation in a fishbone pattern, 3) drip irrigation in a straight-line pattern, and 4) drip irrigation in a zigzag pattern. Piles were watered every 7 days, and data on temperature and moisture content in the compost piles were collected every 5 days throughout the 61-day experiment. Upon completion of the composting process, organic matter content and pH levels were analyzed. The results indicated that drip irrigation in a zigzag pattern, applying 40 liters of water per week, was the most efficient method. This pattern resulted in an organic matter content of 47.1% and a pH level of 8.16. The compost produced through this method exhibited characteristics of being loose, crumbly, and dark brown in color, suitable for soil improvement purposes.

1 Introduction

The demand for organic fertilizers is rapidly growing along with the increasing consumer interest in organic agricultural products and chemical-free foods. In 2021, Thailand had approximately 48,000 ha of organic farming land, with a domestic market value of about 84.3 million dollars and exports valued at 30 million dollars, growing at an annual rate of 20% [1]. The Thai government aims to expand this to 96,000 ha. A key aspect of organic farming is the avoidance of chemical fertilizers, which has led farmers to turn to bio-compost and soil improvement using organic matter.

Furthermore, national policy discourages the burning of agricultural waste in order to reduce air pollution and PM2.5 particulate matter. This encourages the use of agricultural residues for composting, which in turn reduces the need for imported organic fertilizers and chemical fertilizers in agricultural production, aligning with the policy of expanding organic farming [2].

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Moisture content fundamentally affects compost dynamics. Most studies report an optimal range of 40–65% to balance microbial activity and aeration [3]. Moreover, water facilitates key pathways such as hydrolysis and microbial respiration that are critical throughout compost maturation [4]. Regular water supplementation has been shown to extend thermophilic stages and elevate compost maturity indicators like GI above 120%, compared to phytotoxic outcomes (GI <80%) when water schedules are insufficient [5].

Traditional composting takes 5-6 months and requires regular watering and turning of the pile, which is labor-intensive. Labor shortages in agriculture often lead farmers to burn waste instead. Therefore, this research focuses on developing a non-reversible composting method with an automated watering system to reduce labor, providing a more efficient and sustainable solution for farmers.

The objectives of this study are: (i) to develop and optimize watering patterns that ensure the stability of non-reversible compost piles, and (ii) to identify and evaluate the most suitable watering system for sustaining efficient composting under non-reversible conditions.

2 Materials and Methods

This research was conducted at Kasetsart University, Bangkhen campus, Bangkok, Thailand. The scope of the research included designing and comparing different watering patterns, and analyzing the physical and chemical properties of the compost produced.

2.1 Materials and Experimental Setup

The composting mixture was prepared using chopped leaves, dried cow dung, and mature compost at a 4:1:1 volumetric ratio, which aligns with commonly used proportions in manure–bulking agent composting systems [6]. Each compost pile was 1 meter in width, 2 meters in length, and 0.5 meters in height. After mixing the compost, it was piled to the specified size and covered with a transparent plastic sheet to protect it from rainfall (Fig. 1). Fig. 2 shows the experimental layout. The diagram illustrates the arrangement of the water tank, control box, solenoid valve, and the four compost piles. Each pile was subjected to a different watering pattern to compare its effectiveness under the same environmental conditions. An automated watering system was set up using a control box with a Sonoff Wi-Fi smart switch, a solenoid valve, water pipes, and drip emitters (flow rate of 4 liters/hour).

Fig. 1. Pile setup.

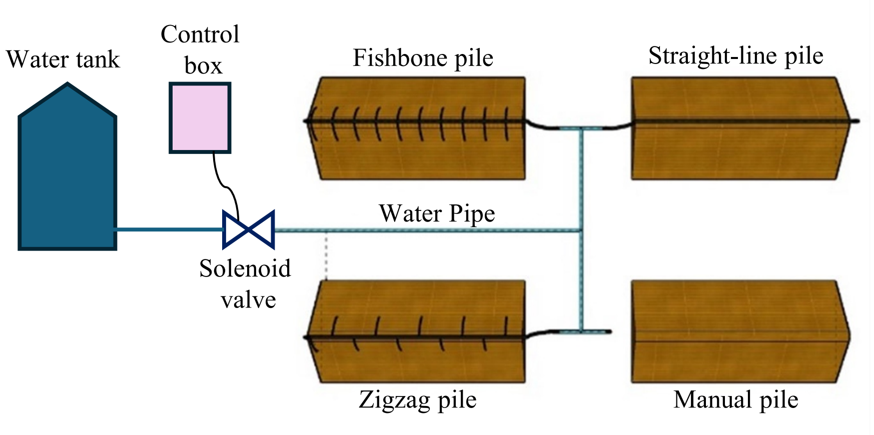
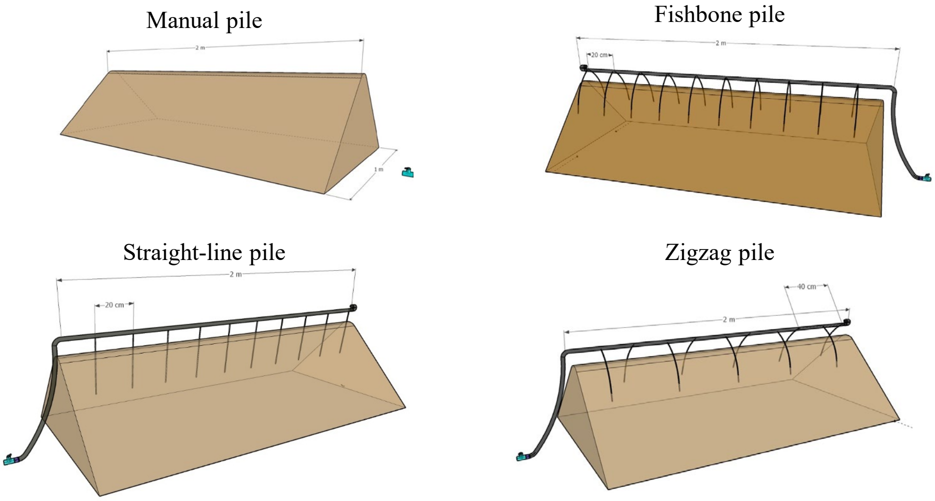


Fig. 2. Experimental layout.

2.2 Experimental Design

Water was applied to the piles every 7 days. Four different watering patterns were tested, as shown in Fig. 3:

1. Manual Watering (Control): conventional watering with a person, with moisture maintained at 50–60%.
2. Fishbone Drip Irrigation: drip irrigation system with pipes laid out in a fishbone pattern, 20 drip heads, total flow rate = 80 L/H.
3. Straight-Line Drip Irrigation: drip irrigation system with pipes laid out in parallel straight lines, 10 drip heads, total flow rate = 40 L/H.
4. Zigzag Drip Irrigation: drip irrigation system with pipes laid out in a zigzag (alternating) pattern, 10 drip heads, total flow rate = 40 L/H.


Manual pile

Fishbone pile

Straight-line pile

Zigzag pile

Fig. 3. Watering patterns.

2.3 Data Collection and Analysis

The experiment was conducted over a period of 61 days. Temperature and moisture content within the compost piles were measured at 3 points per pile every 5 days using a ProCheck soil temperature and moisture sensor. At the end of the experiment, compost samples from each pile were collected and analyzed for organic matter (OM) content (Walkley & Black method) and pH levels at the Department of Soils Science, Faculty of Agriculture, Kasetsart University.

3 Results and Discussion

3.1 Temperature and Moisture Profiles

Temperature and moisture are critical factors for microbial activity in composting. Fig. 4 and 5 present the average temperature and moisture content within the compost piles of four experiments. The temperature in all piles increased to the thermophilic range (above 40°C) within the first 5-10 days, indicating active decomposition. The internal temperature gradually increased, peaking at around 30 days, and subsequently declined until it equilibrated with the ambient temperature outside the piles. In the fishbone pattern, with weekly watering of 80 liters, temperature was slightly higher compared to the other experiments. In contrast, the manual watering showed a slower increase in temperature than the others, although the overall trend of temperature remained consistent with the other experiments. The zigzag pattern maintained the most consistent temperature and moisture levels throughout the pile, avoiding dry spots and promoting uniform decomposition.

The changes in moisture content within four watering experiments show that the overall moisture content across all treatments ranged between 50% and 65% during composting period. The optimal moisture percentage (40-65%), the even distribution of that moisture is crucial. Non-uniformity leads to dry pockets that inhibit microbial activity and overly wet zones that can become anaerobic, both of which result in incomplete decomposition and lower quality compost [7]. The fishbone pattern consistently exhibited slightly higher moisture levels compared to the other experiments, particularly during the early and middle stages of composting. In contrast, the manual, straight-line, and zigzag experiments displayed relatively similar patterns, with fluctuations occurring around the 50–60% range. It was also found that water application influenced both temperature and moisture inside the compost piles, as water facilitated a faster decomposition process.

A one-way analysis of variance (ANOVA) was conducted to validate the observed differences in temperature and moisture among the four watering patterns. For the average temperature, the results showed no statistically significant difference among the watering patterns, $F(3, 24.32) = 0.159$, $p = 0.923$. This suggests that while minor fluctuations were observed, all watering patterns maintained temperatures within a similar thermophilic range suitable for decomposition.

However, the one-way ANOVA for average moisture content revealed a statistically significant difference among the groups, $F(3, 44) = 3.94$, $p = 0.014$. A Tukey post-hoc test was performed to identify specific differences. The fishbone pattern resulted in significantly higher moisture content compared to both the straight-line (mean difference = 3.26, $p = 0.045$) and zigzag patterns (mean difference = 3.61, $p = 0.022$). No significant difference was found between the fishbone and manual watering patterns ($p = 0.052$), nor among the manual, straight-line, and zigzag patterns themselves. This statistical evidence supports the observation that the fishbone pattern, which received double the water volume, maintained a distinct moisture profile, while the other methods were comparable in moisture retention.

3.2 Compost Quality (Organic Matter and pH)

After 61 days, the compost from each pile was analyzed. The results are summarized in Table 1. The fishbone watering pattern yielded the highest organic matter content (47.3%), indicating the most complete decomposition among the tested methods. Its final pH of 8.05 ± 0.07 is within the ideal range for mature compost. However, the zigzag pattern resulted in 47.1% organic matter (OM) and a pH of 8.16 ± 0.14. When comparing water usage, the zigzag pattern used half the amount of water as the fishbone pattern. Therefore, the zigzag pattern was the most efficient pattern, considering the amount of water used, organic matter content, and pH values. The compost produced through this method exhibited characteristics of being loose, crumbly, and dark brown in color, which is desirable for soil amendment.

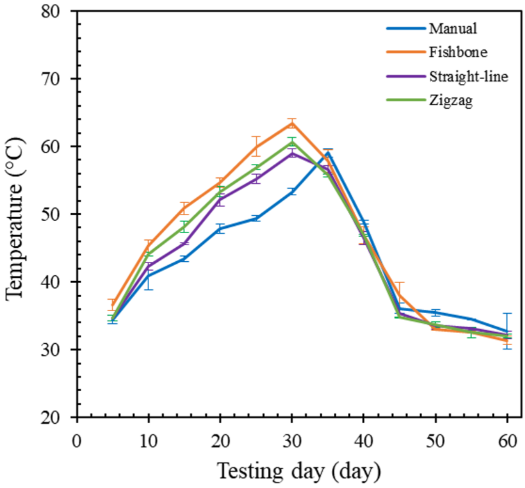


Fig. 4. Temperature changes in the compost piles over 61 days.

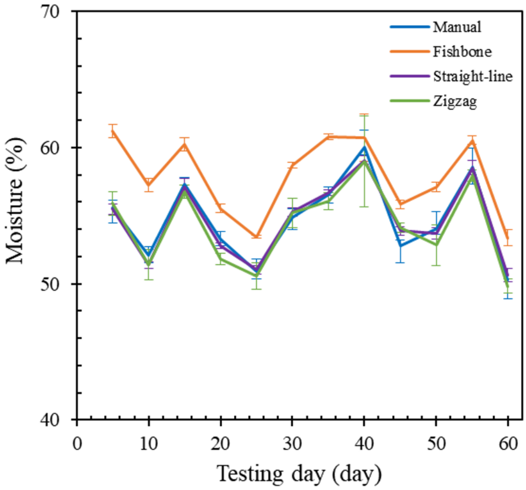


Fig. 5. Moisture content changes in the compost piles over 61 days.

Table 1. Organic Matter (OM) and pH of compost from different watering patterns.

Watering Pattern	**Organic Matter (OM), %**	**pH**
Manual	38.2	7.99 ± 0.22
Fishbone	47.3	8.05 ± 0.07
Straight-line	40.9	8.03 ± 0.05
Zigzag	47.1	8.16 ± 0.14

4 Conclusion

This study demonstrated that among the four patterns tested, the zigzag drip irrigation system proved to be the most effective and efficient method for producing non-reversible compost piles. This method maintained optimal moisture and temperature distribution, resulting in the most efficient pattern and producing high-quality compost with 47.1% organic matter and a pH of 8.16 ± 0.14. This research provides a practical and efficient solution for farmers to manage agricultural waste and produce their own organic fertilizer, contributing to more sustainable agricultural practices.

Acknowledgements

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