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# Urban Soil Enzyme Activity Restoration with Sandwich Compost †

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**Abstract:** Soil enzyme activity is a good indicator of soil quality. Urban soil is known to be of poor quality for plant growth. Meanwhile, food waste is a significant issue around the world. Sandwich compost made using food waste has the potential to improve soil quality. The objective of this study was to determine the effect of Sandwich compost on soil enzyme activity. It was conducted using soil-to-Sandwich-compost ratios of 1:1 and 1:2 for 2, 4, 6 and 8 weeks. Then, the soil enzyme activity, pH and moisture content were determined. The findings show that soil pH was stabilized to 7 after 6 and 8 weeks of restoration at the 1:2 ratio. The 1:2 soil-to-Sandwich-compost ratio significantly increased soil moisture content from 12.00 $\pm$ 0.286 to 14.3 $\pm$ 2.11%. Soil urease activity was enhanced from 1.330 $\pm$ 0.0407 to 10.5 $\pm$ 0.315 mg $NH_3$-H after 8 weeks of restoration, with the opposite effect occurring in catalase activity (0.525 $\pm$ 0.0104 to 0.0839 $\pm$ 0.00535 mL 0.02 mol/L $KMnO_4$/g dry soil). An 8-week soil-restoration period with a 1:2 ratio of soil-to-Sandwich compost is recommended to improve soil enzyme activity and pH.

**Keywords:** urban soil; Bokashi; kitchen waste; soil stabilizing; soil amendment

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## 1. Introduction

Soil enzyme activity is one of the best indicators for soil quality [1]. Soil enzymes are stable proteins with a catalyst function. They mainly come from plant root residue and animal and microbe excretions, which turn organic compounds into inorganic compounds [2]. Soil enzyme activity plays an important role in the nutrient cycle. For instance, proteases, amidases, urease, and deaminases are involved in the N cycle. However, the nutrient cycling is interrupted, and soil organism activity is modified in urban soil. With the help of vegetation and ecology restoration, it improved soil nutrient and enzyme activity, such as catalase and dehydrogenase enzymes [3,4].

Soil enzymes are sensitive to the conditions in which they work, including pollution and aeration. Among the pollutants contained in urban soil are heavy metals (e.g., Zn, Pb and Cd) [5]. Thus, urbanization is gradually making us prone to food insecurity and increasing our carbon footprint through food transportation. Generally, Malaysia has acidic soil, which is known to be less fertile, hence it has lower agronomic potential. This is common in the soils of the equatorial region. Being a hot and humid country, the rate of nutrient loss is high in Malaysia. Acid soil and anthropogenic activity are often related to low microbial biomass and enzyme activity [1]. These factors may be obstacles to the alleviation of the demand for nutritious food.

On the other hand, food is fundamental to human development. About 30%–35% of total food production (~1.3 billion tonnes food and USD 1 trillion) is wasted (non-recyclable) annually [6]. Food waste is a global issue; however, it is a novel problem in Malaysia, as the amount of food waste has only increased recently. Looking at the bright side, food waste could possibly provide the nutrients for our next meal. Food recycling by composting and fermentation is required to solve the downstream issues of food waste and thus contribute to SDG 12: Responsible consumption and production, and SDG 13: Climate action.

Sandwich compost is commonly known as Bokashi. It is a highly versatile method of digesting organic materials, such as food waste, anaerobically. It is environmentally friendly, as it produces low amounts of greenhouse gas emissions [7]. Sandwich compost is also known to have a positive effect on soil properties [8] However, no previous study has been carried out on urban soil enzyme-activity restoration. Previous studies have focused on vermicompost or on utilizing other compost as soil-restoration measures. There is lack of research regarding the effect of Sandwich compost on soil enzyme restoration. The objective of this study is to determine the effects of soil enzyme activity changes with assorted Sandwich compost ratios and restoration periods.

## 2. Materials and Methods

### 2.1. Site Study, Experimental Design and Treatment

The experiment was carried out in a greenhouse located in the Faculty of Agriculture, University Putra Malaysia (UPM) with the coordinates of latitude 2°59′31.4″ N and longitude 101°42′52.1″ E. The studied soil was clay. The experiment was conducted using completely randomized design (CRD) with 4 replications of Sandwich compost treatments for different soil-restoration periods (2, 4, 6 and 8 weeks) and different ratios of soil-to-Sandwich compost (1:1 and 1:2). The experiment was conducted as destructive sampling with 32 sampling units, in total.

### 2.2. Sandwich compost Soil-Restoration Treatment

The Sandwich compost preparation method was modified based on a method by [9]. The 20 cm depth of urban soil was collected from Field 10, UPM. The fresh soil was sieved at 2 mm and mixed well with Sandwich compost in the ratios of 1:1 and 1:2 (in weight basis). Polybags measuring 10 × 10 cm were filled with 1.3 kg of urban soil mixture per polybag, covered with 0.7 kg urban soil and covered with a plastic gunny bag. No irrigation was provided during the restoration period. The Sandwich compost consisted of 1.722 ± 0.2560% of total N (digested with wet digestion and determined by distillation and titration).

### 2.3. Soil Analysis

The air-dried soil samples were crushed using mortar and pestle. The soil was then sieved with a 2 mm sieve. Soil texture was determined according to [10]. Soil pH was determined using a 1:2.5 soil-to-water ratio [11]. Soil moisture content was measured gravimetrically using 20g of fresh soil that had been oven-dried at 105 °C until a constant weight was achieved. [11]. Catalase activity was measured by back-titrating residual $H_2O_2$ with $KMnO_4$ [2,12,13]. Urease activity was determined spectrophotometrically [2,14].

### 2.4. Statistical Analysis

Recorded data were subjected to analysis with two-way analysis of variance (ANOVA) with 4 replications using R statistic software. When F was significant at the $p < 0.05$ level, treatment means were compared and separated using Duncan's Multiple Range Test (DMRT).

## 3. Results and Discussions

Soil urease activity had significant negative correlation with soil moisture content. Soil urease activity and pH were positively correlated. Soil moisture content and catalase activity were positively correlated. Urease activity was negatively correlated with pH and catalase activity. Soil pH was also negatively correlated with soil moisture content and catalase activity.

*3.1. Soil pH*

The ratio of soil-to-Sandwich compost and the soil-restoration period had no significant interaction ($p$ = 0.58058) with pH. Soil pH varied significantly over the soil-restoration period ($p = 1.555 \times 10^{-9}$). Soil pH significantly increased between the 4th and 6th weeks of the soil-restoration period (Figure 1A). The ratio of the Sandwich compost in the soil showed the pH stabilization had significant differences ($p$ = 0.009463) in both ratios, which were 1:1 (7.09 ± 0.11) and 1:2 (7.27 ± 0.098). A 1:2 ratio of Sandwich compost significantly improved pH in the soil. Initially, Sandwich compost was produced in anaerobic conditions with the acidic EM addition, and then exposed to aerobic conditions with soil to facilitate soil restoration. Therefore, the pH rose with the aerobic soil restoration [12]. Another possible explanation was that the drought condition increased the soil pH over time [13]. A remarkable result was that the initial urban soil pH increased to the optimum level (pH 5.5–8.8) [15] in weeks 2 (pH 6.78 ± 0.068) and 4 (pH 6.83 ± 0.079) of the soil-restoration period, and thus made the essential nutrients available for plants.

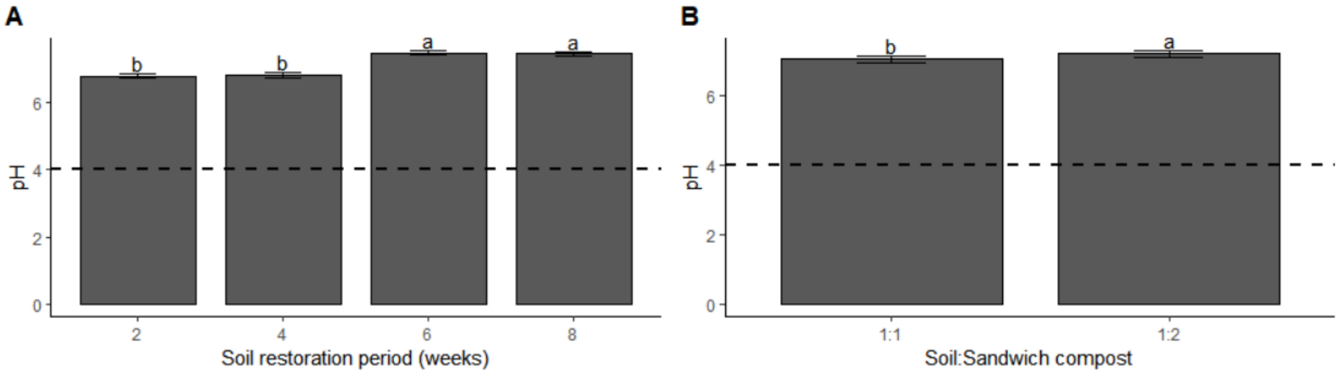


**Figure 1.** (**A**) Effect of soil-restoration period on pH. (**B**) Effect of soil:Sandwich compost ratio on pH. Means ± standard error with different letters is significantly different at $p < 0.05$ using DMRT. The dotted line is referred to as pre-treated soil pH (4.00 ± 0.0473).

*3.2. Soil Moisture Content*

No significant interaction ($p$ = 0.869497) was found between the ratio of soil and Sandwich compost and the restoration period with regard to soil moisture content or the amount of soil water available. Soil moisture content was significantly different depending on the restoration period ($p$ = 0.004833) and ratio of soil and Sandwich compost ($p = 8.576 \times 10^{-10}$) (Figure 2). Soil moisture content significantly declined after week 2 of the soil-restoration period. Nonetheless, the soil moisture content was maintained from week 4 to week 8 of the soil-restoration period. A 1:2 ratio of soil-to-Sandwich compost significantly improved soil moisture content. Soil moisture content is key for soil enzyme activity, as it affects the microbial biomass and respiration [2,16]. Soil moisture content and organic matter had significant correlation with soil enzyme activity, such as arylsulfatase [17,18]. Based on previous findings, a high soil moisture content significantly enhanced soil enzyme activity, such as saccharase, urease, protease, β-glucosidase and acid-phosphatase activity [2]. Catalase activity was also increased with soil moisture content in arable humus and beech forest soil [19,20]. A 20% soil moisture content had significantly higher catalase, urease, alkaline phosphatase, acid phosphatase, β-glucosidase, arylsulfatase and dehydrogenase activity than soil moisture contents of 40% and 60% [20]. On the contrary, any decline in soil moisture content indicated that the actual transpiration rate decreased [21].

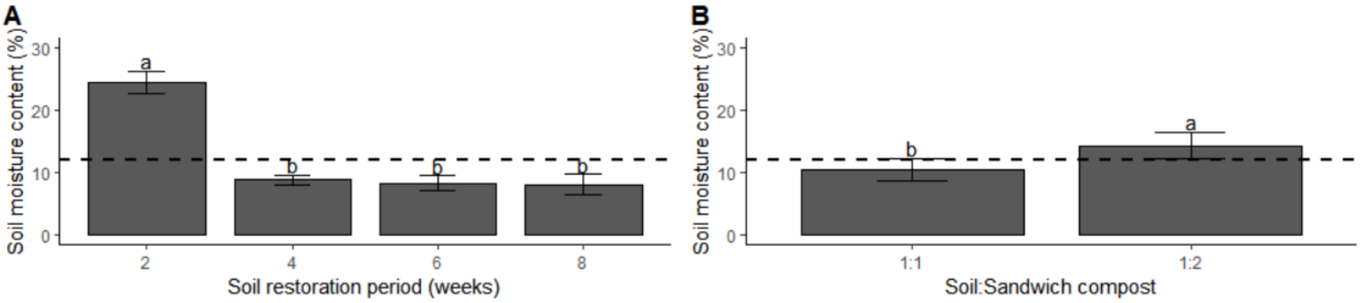


**Figure 2.** (**A**) Effect of soil-restoration period on soil moisture content. (**B**) Effect of soil:Sandwich compost ratio on soil moisture content. Means ± standard error with different letters is significantly different at $p < 0.05$ using DMRT. The dotted line is referred to as pre-treated soil moisture content (12.00 ± 0.286%).

### *3.3. Soil Catalase Activity*

Soil catalase activity significantly increased with the soil-to-Sandwich compost ratios of 1:1 and 1:2 (Figure 3B). However, it significantly decreased over the soil-restoration periods of 2, 4, 6 and 8 weeks (Figure 3A). Soil catalase activity declined 18.22% after applying Sandwich compost. Soil moisture content and catalase activity were closely correlated (0.58). The pre-treated soil was low in organic matter compared to treated soils. However, the catalase activity of Sandwich-compost-treated soil was significantly reduced. Low catalase activity indicated low biological activity in the soil [22]. This was due to the fact that soil moisture content decreased over the drought soil-restoration period, as these factors were positively correlated (Figure 3A). Soil air and water percentages played vital roles in catalase activity. Soil catalase increased in well-aerated soil [23]. Soil pore-size distribution and soil water-filled pore space may indirectly affect the soil enzyme activity, as it significantly affected the bacterial and fungal biomass [24]. The pre-treated soil probably had a large soil pore size, reducing catalase activity.

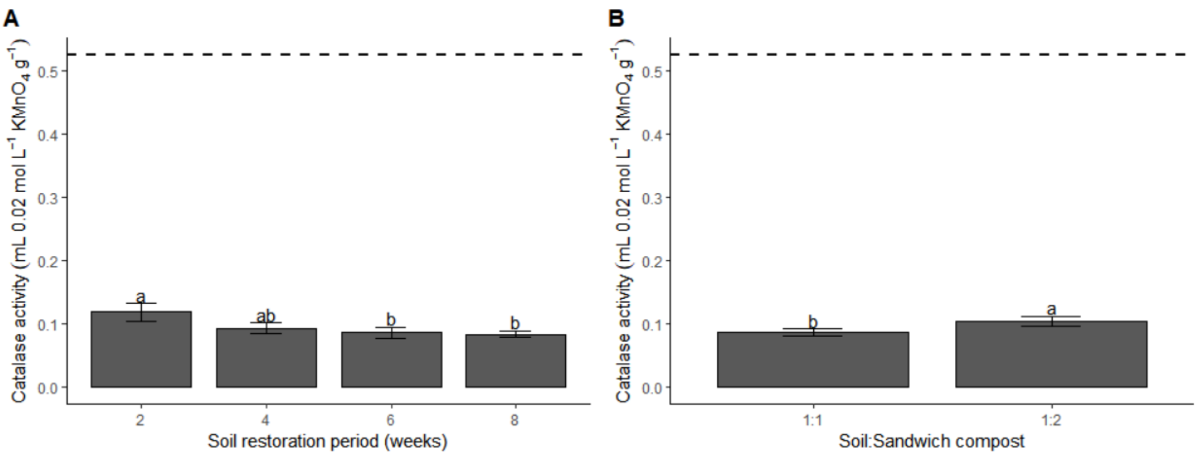


**Figure 3.** (**A**) Effect of ratio of soil-to-Sandwich compost on soil catalase activity. (**B**) Effect of soil-restoration period on soil catalase activity. Means ± standard error with different letters is significantly different at $p < 0.05$ using DMRT. The dotted line is referred to as pre-treated soil catalase activity (0.525 ± 0.0104 mL 0.02 mol $L^{-1}$ $KMnO_4{}^{-1}$).

### *3.4. Soil Urease Activity*

Urease activity significantly increased with a long soil-restoration period (Figure 4). Moreover, urease activity and pH were closely correlated (0.67). Soil catalase activity increased 683.11% after applying Sandwich compost. Urease is a specified enzyme for ammonification. The substrates for ammonification are urea, uric acid and organic nitrogen [25]. In other words, high ammonium is referred to as high urease. Low ammonium is released in soil as the soil moisture content decreases (Figure 2) and pH increases (Figure 1) [25]. Therefore, ammonium concentration may be increased as urease activity increases along the soil-restoration period. In the dry season, urease activity was significantly higher compared to the rainy season [26].

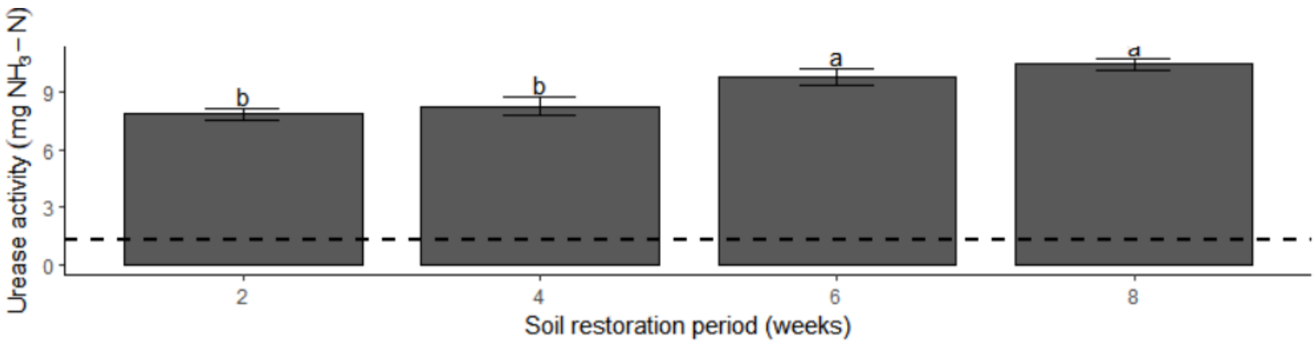


**Figure 4.** Effect of soil-restoration period on soil urease activity). Means ± standard error with different letters is significantly different at $p < 0.05$ using DMRT. The dotted line is referred to as pre-treated soil urease activity (1.330 ± 0.0407 mg $NH_3$-N).

## 4. Conclusions

Amendment of soil with Sandwich compost changed the soil enzyme activity significantly. A two-week period of soil restoration with a 1:2 soil-to-Sandwich-compost ratio is recommended to improve soil urease activity. A 1:2 ratio significantly increased soil moisture content. Nonetheless, soil moisture content and catalase activity decreased simultaneously. Soil urease activity was also enhanced significantly by week 8 of the soil-restoration period as soil pH increased. The optimum soil pH 5.5-8.8 was achieved. Moreover, the production of Sandwich compost is also a good option for effective food waste management.

**Supplementary Materials:** The presentation material can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2022-12198/s1.

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