The Impact of HÜGelkultur Gardening on Ecosystem and Soil Acidity

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Abstract. Hügelkultur gardening is a method that can reuse garbage, such as litter and compost. This kind of reuse brings some benefits: more microorganisms and more nutrients like nitrogen are produced by decomposing. This gardening method did help the environment by decreasing the amount of fertilizers that could harm the ecosystem. However, its potential drawback is that this could increase the acidity in the soil which could negatively impact the environment. For example, from the large activity of microorganisms and their decomposed products, the increase of H^+ ions from nitrification can decrease the soil's pH value. At the same time, the dissolution of CO_2 made by microbial activities produces H_2CO_3, which also reduces the pH level inside the soil. Those characteristics from Hügelkultur gardening unfortunately make the soil more acidic, which could harm the growth of the plant. Therefore, it is practical to propose that people should add egg shells to their composts when using gardening strategies like Hügelkultur, to utilize its alkaline properties for neutralizing the acidity in the soil.

Keywords: Environment; Hügelkultur Gardening; Soil Acidification; Egg Shell; Neutralize.

1. Introduction

Climate Change is a phrase etched in the minds of our generation; people are taught from childhood to be environmentally friendly because there is only one Earth. Currently, many countries have recently taken steps to deal with environmental problems, such as the Paris Agreement across the world, the Clean Water Act in the US and China's South China Sea policy for marine environment protection [1]. As individuals, specifically students' actions often matter too, contributing to wider movements like urban permaculture aimed at climate-resilient farming [2]. The Chinese saying goes from Xunzi: "A journey of a thousand miles cannot be achieved without accumulating every step; a vast river or sea cannot be formed without collecting small streams". Therefore, environmental field students would be more responsible for environmental protection.

The Hügelkultur gardening technique from a video site resembles a hill filled with decaying wood and decomposing leaves with thriving plants [3]. Those who have back gardens in their homes have built this seemingly environmentally friendly method as it reuses decaying wood, decomposing leaves and even waste from the kitchen that would otherwise be thrown in the trash bin. This method is also called "grandma's ways of reusing old debris" and "mound culture" from traditional German and Eastern European societies [4]. Although this gardening method is not widely applied nowadays, mainly due to labor costs and geographical limitations, the environmental benefits it brings are still worth addressing [5].

In addition to reducing the amount of waste people throw away when growing ornamental flowers or even food, this method is also environmentally friendly in other aspects. For example, the logs and branches inside can store a lot of water, and then it will irrigate the soil like a sponge. The logs, branches, and other organic materials will also release nutrients to the soil as they decompose, such as nitrogen, phosphorus, and potassium which the plants need for their growth.

However, a byproduct was found - an effect on soil pH that has a negative influence on the environment, especially for a long period. Specifically, Hügelkultur gardening will somehow decrease the soil's pH, which causes soil acidity to create a variety of negative drawbacks to the ecosystem. As soil acidity affects the nutrient availability of the plant, this will gradually become an issue since those components play a crucial role in photosynthesis, maintaining plant growth, and

enhancing health levels. Those components are essentially important factors to consider since they will affect the harvest of the farm.

Therefore, this research aimed to reduce the impact of decreased pH levels as a side effect of the Hügelkultur gardening method, assisting in creating a healthier and more sustainable environment.

2. Literature Review

Some literature suggests that the Hügelkultur gardening method does not increase soil acidity, such as Longxu Du and his team [6] conducted an analytical study to assess the impact of soil acidification on yields in different soil conditions and crop varieties. The study found that soil acidification resulted in an average yield reduction of 13.7%. Vegetables were the most sensitive to soil acidification, with a 33% reduction in yield, while maize and wheat yields were reduced by 18.2% and 18.3%, respectively. Yields of rice and legumes were not affected by soil acidification. Specific findings included a 25.4% reduction in root length and a 3.1-13.6% reduction in the uptake of nutrients such as nitrogen, phosphorus, potassium, and calcium. Soil total nitrogen content, effective phosphorus, soil organic matter, and exchangeable calcium were reduced by 11.4%, 18.1%, 16.3%, and 76.8%, respectively. Microbial biomass carbon, nitrogen, and phosphorus decreased with decreasing pH.

Nonetheless, more previous research argues that the Hügelkultur gardening method does have an impact on soil acidity, as pointed out in Muthu, N., Shanmugam's research [7] that some moist, decomposing logs in hügelkultur beds could tie up nitrogen and lower soil pH. This is true in the early stages of a hügelkultur bed as decomposing logs and other organic matter with a high carbon-to-nitrogen ratio cause nitrogen immobilization. This process, along with the production of organic acids and nitrification, can lower soil pH and lead to soil acidification. However, as the organic matter breaks down further, nitrogen is released back into the soil through mineralization. Nitrate uptake by plants and the reduced production of organic acids can contribute to a gradual increase in pH. Therefore, decomposing logs in the hügelkultur bed cannot cause a lower soil pH.

Moreover, Du, L. [6] further explains that the effect of applying organic fertilizer on soil pH varies according to soil type and management. On acidic soils, applying organic will significantly increase soil pH, whereas on alkaline soils, applying organic manure decreases soil pH. Pengshun Wang and his team [8] argue: "Under acidic soil conditions (pH<7) with mean annual temperature ≤ 8°C and rainfall of 400-600 mm, organic manure application increased soil pH the most. The increase in pH was 8.07% for low organic matter soils, 6.42% for high organic fertiliser applications and the most significant increase was 7.14% for manure, with medium and long-term fertiliser applications increasing soil pH more than short-term applications. However, under alkaline soil conditions (pH>7), the application of organic fertilizers had the greatest decrease in soil pH, organic fertilizer application significantly decreased soil pH with low organic matter (4.07%), manure and commercial organic fertilizers decreased soil pH about 3.60 times more than bio-organic fertilizers, and the decrease in soil pH increased with the increase in the number of organic fertilizers applied". Soil pH is one of the main determinants of soil excitation effects, which control, among other things, the composition and activity of microbial communities [9]. Negative excitation effects are common at soil pH values below 4.5 or above 7, reflecting a suboptimal environment for microorganisms and specific SOM stabilization mechanisms. Pengshun Wang and his team [8] also argue that "In acidic soils, long-term application of chemical fertilizers led to a decrease in soil pH of up to 1.20 units, whereas chemical fertilizers with organic fertilizers led to a significant increase in soil pH. In acidic soils, soil pH was directly correlated with the abundance of Mortierella, and the enrichment of Mortierella had a direct positive effect on crop yield".

Therefore, the research gap addressed in this study is to verify whether the Hügelkultur gardening method affects soil acidity through a control group experiment, and if so, the proposed solution would be illustrated to mitigate this effect.

3. Methodology

To determine and analyze the effect of Hügelkultur gardening on the soil's health and find the level of the impact on the plant's growth, two comparison groups were conducted. If soil acidity is low, the soil's health is affected, also there will be some impact on the growth rate of the plant. Logs, grass and orange peel were prepared for the organic matter. First, put the logs at the bottom of the box, then add a layer of grass to the logs. Next, some orange peels were laid on the top of the organic layer. The next step was to put the soil layer on top of the organic layer, which prevented space for the plants to live. Finally, the seeds were planted. During the building section, the amount of organic matter was ensured and the soil of the two groups was the same. The next section was adding variables. Eggshells were added to one of the groups, and the other group was the control group. Hügelkultur gardening can increase soil acidity over time, potentially causing a decrease in pH level that could affect soil health and the surrounding ecosystem. Eggshells contain 95-98% of $CaCO_3$ to react with the Hydrogen cation and neutralize the pH to mitigate the damage to the soil and the surrounding ecosystem that is influenced by the Hügelkultur gardening method. During the experiment, the two groups were receiving the same amount of sunlight and getting the same amount of water. Later, the pH of the soil was measured and the two groups were compared. The experiment hypothesis was the group with eggshells would display a higher pH, and the control group would show a lower pH which harms the soil's health. Hence, if the group with the eggshell would get a higher pH, which illustrated a neutralized soil acidity, thus the soil's health would be maintained even through the Hügelkultur gardening method.

4. Results and Analysis

The results showed that the group with eggshells experienced a higher pH compared to the control group, indicating the Hügelkultur gardening method would lower the soil acidity, yet the eggshell would neutralize the soil acidity effectively along with the Hügelkultur gardening method, thus not harming the environment. According to the result, nitrogen contributes one of the most important reasons because it is a critical nutrient for plants' growth as it is a major component of amino acids and nucleic acids, this could also be a main reason why Hügelkultur gardening can potentially cause soil to be acidic. In Hügelkultur gardening, many materials easily decompose, such as pilling logs, branches, sticks, plant waste, and even compost. As microbial communities under this condition can decompose these litter materials, they can release nitrogen into the surrounding area as a by-product [10]. In addition, as the base of the Hügelkultur gardening employed some old and large wood-like logs, they have more ability to contribute more nitrogen toward the soil than normal gardening techniques [11]. At this time, the increase of nitrogen inputs into the soil's ecosystem rather from highly decomposed rate or material that employed itself can all be major contributors to soil acidification as they release lots of protons (H^+) during nitrogen transformations in the soil, which leasing to the cause of the pH decline. Specifically, in a biogeochemical cycle that involves the soil called nitrification, N_2 is initially in this cause of Hügelkultur gardening fixed by an abiotic reason-lightening or biotic reasons like microbes in the plants' nodules. After the next stage of ammonification, nitrification can then release lots of H^+ toward the soil's system, basically from three factors. Firstly, as nitrification facilitates the uptake of ammonium (NH_4^+) by plants, this results in the release of H^+ ions into the rhizosphere. Then, the nitrification of ammonium to nitrate (NO_3^-) generates additional H^+ ions. Additionally, the leaching of nitrate (NO_3^-) in the previous stage of nitrification with accompanying basic cations further leaves behind H^+ ions. Those increases in H^+ ions caused by more nitrogen processes in the soil can influence the soil by increasing permanent acidification, which could harm the natural ecosystem [12].

Microorganisms are a crucial content inside soil since their activities have profound impacts on soil texture, nutrient cycling, and many other components. Specifically speaking, microbial activities will contribute to a decrease in pH level, causing greater acidity inside the soil. This is the main reason why Hügelkultur gardening is somehow environmentally damaging since it contributes to the

downfall of pH level. To begin with, the dissolution of CO_2 produced by microbial respiration formed carbonic acid, which is a source of proton that leads to soil acidification. This process includes several steps. First, during microbial respiration, those organisms break down organic matter that releases CO_2 into the soil. Second, when CO_2 dissolves in the moisture content of soil, it reacts with water to form H_2CO_3. This acid will dissociate and release hydrogen ions back into the soil, causing an increase in soil acidity. Furthermore, researchers have determined that bacterial communities have shown a strong correlation with soil pH, meaning that there is likely a relationship between them. Through different analyses, bacteria, decompose carbon. Additionally, bacteria go through a cycle of fermentation which will produce organic acids as a byproduct. To start with, bacteria absorb simple sugars from the environment. Then, pyruvate will be converted into different processes, aiming for energy production and waste management. However, despite those benefits given to bacteria, the production of different types of acid with the release of hydrogen ions causes a dramatic increase in the concentration of acid. Last but not least, microorganisms' activities could enhance cation exchange capacity inside the soil, leading to the accumulation of Hydrogen ions, increasing the acidity of the soil. An increase in acidity is damaging to the soil since it could impact the availability of nutrients. As soil becomes more acidic, some compounds, such as calcium, become less available based on solubility. On the other hand, acidity also impacts soil development, acidic conditions often directly change plant root structure, making it less able to absorb nutrients and water supply. Meanwhile, this caused plants to have limited growth and further impacted the whole ecosystem. Therefore, Hügelkultur gardening somehow needs improvements since it still has some potential environmental hazards dioxide, strongly contributing to the acidification of soil. To conclude, microorganisms are a major reason why Hügelkultur gardening will end up damaging the health of the soil, which is a reason that we have been working on this topic and trying to improve. Because Hügelkultur gardening has numerous advantages, it is important to get rid of those disadvantages and apply them throughout different countries to reach higher productivity.

5. Discussion and Conclusion

Hügelkultur agriculture practices that increase soil acidity over time may lead to decreased pH levels, which can harm soil health and surrounding ecosystems, aligning with previous research that indicates that illustrates the chemical impact of decomposition on soil. This outcome emphasizes the potential damage of Hügelkultur in affecting soil health and the ecosystem, but also emphasizes the significant effects of changing soil conditions in some alkaline regions, leading to a more beneficial pH range.

Our study expanded to the broader influences of Hügelkultur on the environment, addressing the research question by illustrating how the gardening method influences acidity. Compared to previous studies that mainly focused on nutrients and water, our experiment emphasized the effect on soil acidity, which is generally been less discussed. The finding suggests that while Hügelkultur is considered to be a sustainable agricultural practice compared to others, the chemical change in pH levels will still be an essential issue, that needs to be avoided so the ecological balance will not be broken by changing acidity. The solution is adding eggshells to prevent the process of acidification, which can balance the ecosystem. The results for differences in acidity also illustrate the effects of eggshells of Hügelkultur on acid soil and environment, illustrating its effects for preventing soil acidification.

However, several limitations still existed during the experiment. First, it was acknowledged that not enough space for the two groups, for the reason that the land in the city was limited alongside a large number of citizens. Therefore, the experiment was set up in a narrow space, which might affect the ultimate result for pH due to the insufficient development of the compost. Second, the experiment was conducted over a short period, which might not have fully represented the long-term effects of Hügelkultur on soil pH. Additionally, even though the variables were controlled, the slight difference in the placement of soil may cause some deviations.

To build on this study, future experiments can explore Hügelkultur's effects in the long-term and larger, more diverse environments. Furthermore, the impact on microorganisms and the nutrient cycle should be further explored, illustrating deeper insights into the effects of Hügelkultur gardening. Future experiments could also be focused on the balance between ecological impact and economic effects, which means reducing the cost of Hügelkultur's agriculture practices and maximising the benefits. For example, adding eggshells in acidic environments with acidic soil could reveal its potential to enhance productivity while preventing soil degradation, maximizing its benefits. Additionally, experiments on integrating Hügelkultur with other sustainable methods, such as crop rotation or companion planting, could provide more diverse insights into how Hügelkultur will work. Investigating how different organic matters will bring what change to pH scale can also be explored in the future applications of Hügelkultur. By addressing these findings, future practices can help refine Hügelkultur's practices to be more environmentally friendly while minimizing the risk to soil health and ecosystems.

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