The Effects of Soil Temperature on Soil pH

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Abstract

Over the course of around a month, we have collected data surrounding the idea of how soil's temperature affects its pH, which is important as global warming persists and how it could affect how people grow food and various other plants. Some sources the researchers found in our background research suggested that as the temperature increases, the pH lowers in soil. Our hypothesis for this experiment was that if the temperature of the soil increases, then the soil's pH will decrease because of both Le Chattelier's principle and the fact that warmer climates optimize microbial activity, and thus producing organic acids to lower the pH of the soil. To conduct this experiment, samples of soil were taken at different horizons, and measured the soil temperature and pH. Overall, our results had a general trend that as the temperature increased, the pH level decreased and vice versa. Due to this, the study can conclude that our hypothesis was supported, as a general trend that as the temperature of soil increased, the pH decreased was shown. Some further implications from this study include how these pH changes will affect plant growth in the future, as the world continues to increase in temperature.

Introduction

Both temperature and pH are considered critical “master variables,” or key variables that significantly influence other variables for soil. These two properties are responsible for influencing the processes that take place in soil, along with nutrient availability, microbial activity, and plant growth. Although these two features work together to control soil life, soil pH can actually be affected by soil temperature. Soil temperature and pH tend to have an inverse relationship, meaning that as the temperature increases, the pH of the soil decreases, meaning that it becomes more acidic. This is primarily because of Le Chatelier’s principle, which asserts that if a system at dynamic equilibrium is subjected to a change, it will shift its equilibrium position to counteract that change, and because increased temperature tends to lead to increased microbial activity and organic acid production. Additionally, increased temperature is associated with increased bacteria productivity, resulting in the increase in the production of organic acids.

One key reason soil behaves as it does is due to Le Chatelier’s Principle. This principle states that if a system at dynamic equilibrium is changed, like in temperature, concentration or pressure, the equilibrium position will shift to counteract the change the system is facing (Atlas Scientific, 2025). To connect this to soil, many chemical reactions involving hydrogen ions (H^+) are in equilibrium, particularly those associated with organic matter decomposition and nutrient cycling (Wang & Tang, 2018). As the soil temperature increases, reactions that produce these ions are favored, causing the equilibrium to shift towards acidity. This results in a lower pH, as higher amounts of H^+ ions are released into the soil. Consequently, Le Chatelier's principle helps explain this inverse relationship between soil temperature and pH, illustrating how temperature changes can indirectly alter the soil's chemistry.

Another key reason soil behaves as it does is due to the idea that, as temperature increases, so does bacteria productivity. The main reason for this is that warmer conditions enhance the rate of biochemical reactions within microbial cells. Most bacteria operate more efficiently within a moderate temperature range, where enzymes involved in metabolism function at optimal speeds. When temperature increases, enzymes collide with substrates more frequently, accelerating processes such as respiration, decomposition, and nutrient mineralization. This results in certain bacteria making things like carbon dioxide and organic acids, which can influence pH (Khan et al., 2025).

In conclusion, although both temperature and pH are "master variables" that are critical factors that work together to help determine soil quality, the pH level of soil can actually be influenced by the temperature. Increased temperature can lead to lowered pH levels because of Le Chatelier's principle, which states that if a soil sample experiences a temperature increase, the increased ionization from the equilibrium counteracting the temperature increase will cause an increase in H^+ ions, and also because of increased microbial activity, which will result in an escalation of organic acid production.

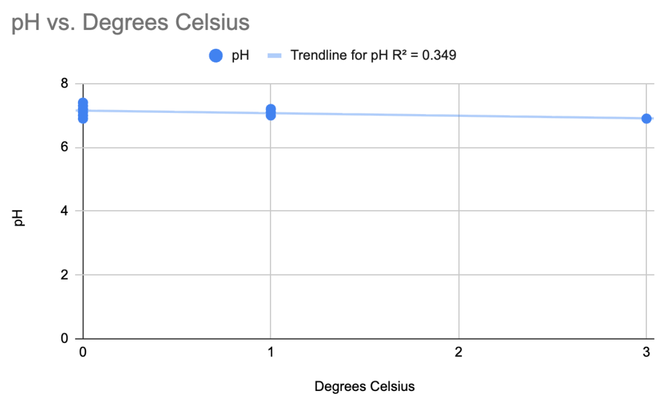
Methods and Materials

The materials that were used in this experiment were a digital soil moisture meter (which measures soil pH & temperature), a shovel, a cup, water, a ruler, some paper towels (for cleanup), and a computer to record data.

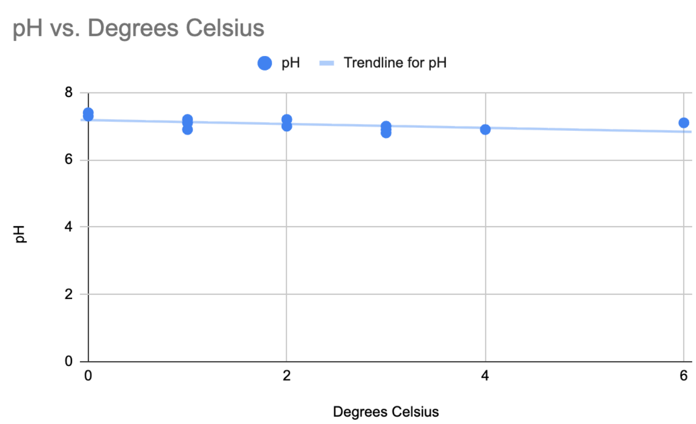
To do this experiment, first a 1 inch deep hole was dug into the ground, and the digital soil moisture meter was used to evaluate the soil temperature. After that, a small sample of soil from the hole was dug out so that it would be able to fill the bottom of the cup and it was then inserted. Proceeding that, just enough water was added into the cup so the mixture became a liquid, then the digital soil moisture meter was used to measure the pH level of the water and soil mixture. Then the cup was cleaned for the next trials and the data was recorded. The procedure up to this point was repeated twice more, so that 3 data points were collected at 1 inch deep. Subsequently, 3 holes 5 inches were dug into the ground, then, the same steps from "using the digital soil moisture meter to evaluate the soil" to "cleaning up the cup for the next trials and recording data" were repeated 3 times. Finally, 3 holes 10 inches were dug into the ground, and then the same steps were repeated as listed in the previous sentence. The data was then submitted into GLOBE.

Presentation of Data and Results

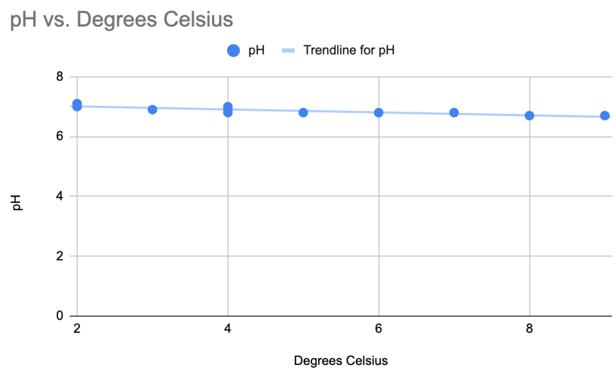
1 inch:



5 inch:



10 inch:



Overall, our results show a declining trend for pH and temperature increases. Although the slope at which the pH is declining isn't strong, and some outliers that do not follow the trend are present, the data is still consistent enough to show a trend indicating a negative correlation between the two properties.

Analysis and Results

This study demonstrates an inverse relation of a soil temperature and pH. Throughout the graphs of our data, there was overall a slight downward slope in terms of pH as the temperature in celsius went up. Overall, this data supports the hypothesis that was thought of before the experiment, which was that if the temperature of the soil increases, then the soil's pH will decrease because of both Le Chattelier's principle and the fact that warmer climates optimize microbial activity. Overall, this study both matched our hypothesis and other similar studies. We believe that we achieved these results due to Le Chattelier's principle, which is that if a system at dynamic equilibrium is changed, like in temperature, concentration or pressure, the equilibrium position will shift to counteract the change the system is facing. This can lead to more or less hydrogen ions being produced, changing the pH. We also believe that bacterial growth takes place more frequently if the temperature of a soil and vice versa, leading to pH changes from the products of the bacteria. Some areas that could be improved include conducting this experiment across a longer period of time to get a wider range of temperature, and having more precise measuring tools, as the probe we used to measure the soil temperature would not go below 0 degrees celsius. In conclusion, this experiment tested this hypothesis quite accurately, and provided evidence that supported said hypothesis.

Conclusion

Overall, our results supported our hypothesis that an increase in soil pH decreases its pH level because our results indicate a negative relationship between temperature and pH, as the pH level declined overall as the temperature of the soil increased. Since our results aligned with our hypothesis, we believe that we were able to obtain these results because of the negative correlation between temperature and pH due to Le Chatelier's principle and also due to increased microbial activity at a higher temperature.

We would consider our experiment successful, as we collected multiple points of data which all manifested consistent trends that aligned with our predictions. However, if we were to repeat our experiment, we would have increased the period of time for data collected so that we could obtain data at a wider range of climate, and we would also test multiple sites to see whether the trend we observed was exclusive just to our data collection site or to soil in general. Although we weren't able to find any data on GLOBE or NASA that measured both soil pH and temperature, we were able to find some related experimental data online, where it was concluded that an increase of temperature acted as a catalyst for microbial activity and therefore affected the pH of the soil in a similar manner to our results.

Discussion

One issue we had with this experiment was that our device to measure the soil temperature could not measure temperatures below 0°, making our data not as diverse. If we were to do this experiment again, we would collect data over a longer course of time so that we can get various data for different seasons, and we would also test more sites of soil to determine whether the observed trend was exclusive to just one data collection spot or was common in all soil.

We believe that our experiment was able to accurately test our hypothesis because although our range of temperatures measured was not broad, the trend was visible in all of our data, meaning that our repetitive trials yielded consistent results. A further inquiry we developed while conducting our experiment that would require further investigation was whether this trend would still be visible in both sterilized soil or living soil, or in other words, if the trend we observed in our data would still be visible if we tested with soil lacking biological activity. We believe our research could be helpful and used for agricultural purposes, particularly for crop modeling, as an altered pH in the soil due to temperature change could have drastic effects on the crops that grow in the soil. We also believe our data could be useful for further analysis of microbial activity in soil, to see how soil health changes as the temperature changes.

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