THE EFFECTS OF SIMULATED ACID RAIN ON CORN SEED GERMINATION

July 24, 2013
ABSTRACT

Acid precipitation is any type of precipitation with a pH lower than 5.6. There are many variations of acid precipitation including rain, snow, dew, hail, and fog. Acid rain specifically is an issue that affects both organisms and environments around the world. Acid rain has been shown to affect many crops and plants. In our study we decided to explore the effect of acid rain on corn seed germination, which is important because the Northeastern region of the United States, including Maryland, has the most acidic levels of rainfall in the country. However, Maryland also has a large number of rural areas that depend on the growth of crops such as corn. Corn is an important cash crop to the area and generates a great deal of revenue, so it would be valuable to understand what effects acid rain might have on the development of corn seeds. For this reason, we saw it imperative to discover the effects of simulated acid rain on corn seed germination. We hypothesized (H₀) there will be no significant difference in the average number of days it takes for corn seeds to complete germination and the difference between the percentages of corn seeds that complete germination within a seven-day period among corn seeds treated with any of the pH values tested. We placed our corn seeds in several planters, each filled with simulated acid rain having a pH of 3.0, 4.0, 5.0 or 6.0. We then recorded data for the number of days it took for each stage to occur in each seed. We collected data for seven days and compared the results for each pH level. We performed a z-test to determine if there was a significant difference in the percentages. We failed to reject our null hypothesis (H₀) for averages because our results showed that the average number days it took for the stages to occur in seeds treated with all pH levels was the same. We rejected our null hypothesis for percentages because we found that there was a difference between seeds treated with pH 4.0 and 6.0 and pH 5.0 and 6.0. Therefore, the results of our study indicated that while acid rain does not affect the germination of corn seeds, it does affect the percentage of seeds that complete germination. However, further research is necessary to determine how the simulated acid rain may affect later growth and yield of corn crops. This is of particular concern because in soil, the natural limestone bases and traces of calcium buffer the acidity of the water entering said soil through precipitation. Farmers commonly alter the pH of soil through liming to assist the buffering of acid precipitation, and determining the effect of simulated acid rain on corn seed germination in soil is important because it could reveal the effective pH of water after it has been neutralized by the buffered soil.
INTRODUCTION

Acid rain occurs in many places all around the world, including the United States and Germany. Acid rain is a type of acidic deposition—particles deposited from the atmosphere. Acid rain and other types of acidic deposition, such as acid snow, hail, dew, and fog, form when sulfur dioxide (SO$_2$) and nitrogen oxides (NO$_x$) physically and chemically react with sunlight and water vapor (Chesapeake Bay Ecological Foundation, Inc., 2013; National Atmospheric Deposition Program, n.d.). SO$_2$ and NO$_x$ are emitted from both anthropogenic, or manmade, and natural sources. Some anthropogenic sources are motor vehicles, fossil fuels, factories, and power plants, while natural sources include volcanoes, wild fires, rotting vegetation, and lightning (Chesapeake Bay Ecological Foundation, Inc., 2013; USGS, 2013). The measured pH value of a substance determines its acidity. The pH value is the concentration of hydrogen ions (H$^+$) in a substance and is measured on a scale of 0.0 to 14.0; values less than 7.0 are acidic, and those more than 7.0 are basic (Chesapeake Bay Ecological Foundation, Inc., 2013). Pure water (H$_2$O) has a pH of 7.0, making it neutral. The United States’ national average pH of rain is between 5.6 and 6.2, and any rain that has a pH lower than 5.6 is considered acid rain (National Atmospheric Deposition Program, n.d.). Acid rain particularly affects the Northeastern region of the United States because it has a dense population with many cities and fossil-fuel burning power plants, and the prevailing wind direction of the United States directs pollutants such as SO$_2$ and NO$_x$ from the West towards the Northeast, allowing for an increase in acid rain (USGS, 2013). Acid rain and the other acidic depositions have many effects on the environment and humans.

Acid rain can alter the pH of water masses, such as lakes, ponds, and streams, and soil by decreasing the overall pH of the water (Chesapeake Bay Ecological Foundation, Inc., 2013; National Atmospheric Deposition Program, n.d.). Lakes and soil often have a basic pH value, acting as a buffer, or neutralizer, for acidic depositions, but if there is too much acid rain, the pH of the water and soil may lower to a point that negatively affects the wildlife, such as fish that go into shock and die due to water with a low pH (Chesapeake Bay Ecological Foundation, Inc., 2013; National Atmospheric Deposition Program, n.d.). Acid rain can also increase the natural rate of deterioration of rocks and some metals, which can lead to the destruction of stone buildings and metallic structures (USGS, 2013). In particular, acid fog, affects humans by surrounding them with the acidic water vapor, which humans can inhale, causing a variety of respiratory problems including asthma (National Atmospheric Deposition Program, n.d.). Additionally, acid rain can destroy the leaves of plants, such as the needles on the Evergreen Pine trees in Black Forest, Germany, where all of the trees are barren of needles and the trunks are black due to excessive acid rain (USGS, 2013). Acid rain also affects crops by changing the chemical properties of the soil, reducing soil nutrients, and slowing the rates of processes within the crops (National Atmospheric Deposition Program, n.d.). Previous scientific studies that looked at simulated acid rain’s effects on crops found that the acid rain may stunt, slow down, or even improve root development and overall growth of the crops (National Atmospheric Deposition Program, n.d.).

Several previous studies have shown the effects of simulated acid rain on common crops in the United States. Lee et al (1980) found that acid rain enhanced the productivity of several crops, including potatoes, alfalfa,
tomatoes, green peppers, and strawberries. These crops had significantly larger yields when treated with pH 4.0 and 3.5 simulated acid rains (Lee et al, 1980). Lee et al (1980) also reported that pH 3.0 simulated acid rain significantly, however marginally, increased the total yield of corn, although it had foliar injury. Though the simulated acid rain enhanced the crops’ growth and yield, many of them still featured some kind of foliar injury. Evans et al (1982) observed the effects of simulated acid rain, at varying pH levels of 5.7, 4.0, 3.1, and 2.7 on yields of radish, garden beet, kidney bean, and alfalfa. Evans et al (1982) found no significant difference in the yields of radish, kidney bean, and alfalfa, but found a significant decrease in the yields of garden beets that they had treated with simulated acid rain when compared to the yields of garden beet treated with pH 5.7 simulated rain. The beets accumulated lesions on their leaves, a form of foliar injury (Evans et al, 1982). Singh and Agrawal (2001) studied the impact of simulated acid rain, of pH levels 5.6 (control), 5.0, 4.5, 4.0, and 3.0, on the growth and yield of two types of wheat, Malviya 213 (M213) and Sonalika (Singh & Agrawal, 2001,). Singh and Agrawal (2001) reported that the shoot and root lengths, leaf areas, and total biomass or yield of both types of wheat declined significantly at or below pH 4.0 (Singh & Agrawal, 2001,). Singh and Agrawal conclude that simulated acid rain had a significantly negative effect on wheat (Singh & Agrawal, 2001, p. 71).

Along with the studies of Evans et al. (1982), Singh and Agrawal (2001), and Lee et al. (1980), other studies tested the effects of simulated acid rain on other crops. Munzuroglu et al. (2002) studied the effects of simulated acid rain on pollen development and pollen tube growth of apples. Munzuroglu et al. (2002) reported that pH levels below 3.1 destroyed the pollen tubes and that pollen development stopped near pH 3.0. Munzuroglu et al. (2002) concluded that both the pH value and quantity of the rain was an important factor in the development of apples. Wertheim and Craker (1987) studied the effects of acid rain on pollen development in corn, specifically looking at corn silks. Wertheim and Craker (1987) reported that the pollen was unable to develop due to the acid rain and concluded that the acidity of the rain directly influence the reduced pollen development, suggesting that the more acidic the rain was, the less development occurred. Wertheim and Craker (1987) also suggested that the acid rain might have caused physical and chemical modifications to the silks’ surfaces in order to reduce the development of pollen, but not because of acid that remained on the silks’ tissue. Additionally, Wertheim and Craker (1987) concluded that the reduction in pollen development may result in fewer corn seeds, thus resulting in less yield overtime. Wertheim and Craker’s 1987 study shed some light on the negative effects that acid rain may have on corn and corn seeds, a very important crop for the United States, especially Maryland.

The life of a corn stalk begins with its seed. A seed is quiescent, or resting, organ encased by a testa—a hard seed coat—that houses the embryo of the plant and the endosperm, which is a tissue that surrounds the embryo to give it nutrients (Hopkins, 1999). The embryo makes up the leaves, roots, and stem of the plant. Seeds generally have about 5% of their body weight in water, making them dehydrated with very low metabolisms. This low metabolism leaves seeds in a state of suspended animation, allowing them to withstand adverse conditions for long periods. Germination is the process in which the life of a plant renews, resulting in the emergence of the roots through the testa (Nielson, Root, 2010). Germination begins with imbibition—the uptake of water (Hopkins,
After the seed absorbs about 30% of its body weight in water through imbibition, metabolism increases and the visible stages of germination begin (Hopkins, 1999; Nielson, Root, 2010). Germination only requires a temperature of 10°C or 50°F and water to begin, not soil (Nielson, Requirements, 2010). The first visible stage of germination is the emergence of the radicle root, which emerges from the bottom of the seed. The radicle root acts as an anchor for the seed and allows for the emergence of the other roots. The second visible step of germination is the emergence of the coleoptile from the side of the seed. The coleoptile brings the embryonic leaves to the surface of the soil, if planted in soil, and eventually becomes the shoot of the plant. The third and final visible step of germination is the emergence of the lateral seminal roots. The lateral roots emerge between the radicle root and the coleoptile and initiate the secondary or nodal root system. The emergence of the lateral roots indicates the end of germination (Hopkins, 1999; Nielson, Root, 2010; Nielson, Visual, 2010).

Understanding how corn seeds germinate is very important for our study. The purpose of our study is to observe the effects of simulated acid rain on corn seed germination. Our study is important because if we discover that there are negative effects to corn seed germination due to simulated acid rain; farmers that cultivate corn could take precautions to protect their crops against possible destruction and reduced revenue. However, if we discover that simulated acid rain has a positive effect on corn seed germination, such as decreasing the amount of time that it takes for germination to complete, farmers could take steps to treat their crops with acidic solution so that they could farm more corn in a single season to increase revenue. Additionally, Maryland has the most acidic rain in the United States, holding a record of pH 2.9 acid rain. The national average pH for precipitation is 5.6 to 6.2, and pH 3.0 is 1,000 times more acidic that pH 6.0, making pH 2.9 much more acidic than the national average. Much of Maryland is rural, only having a few major cities and many farms, most if not all of which grow corn. Approximately 500,000 acres of corn are planted every year. In 2011, corn sales rewarded Maryland with about $241 million in revenue, making corn 12% of Maryland’s cash crops (Maryland Department of Agriculture, 2013). Corn is also used in many products, such as feed for chicken, cows, and pig, corn syrup for sodas and many other products, and basic consumption for humans around the world (Maryland Department of Agriculture, 2013). With the large abundance of corn that farmers grow in Maryland and Maryland’s acidic rain, our study is very important for Maryland’s agricultural health.

We decided on our experimental design for several reasons. We chose to use cotton balls to house the seed instead of soil because cotton is able to evenly absorb water for distribution to the seed, and we can readily view the seed during the study without disturbing it, which could occur if we were digging the seeds out every day to view them. We chose the pH levels of 5.0, 4.0, and 3.0 for our simulated acid rain because those pH levels, or ones similar to them, were used in previous studies, giving us results that we can compare our study (Evans, Lewin et al., 1982; Lee et al., 1980; Munzuroglu et al., 2002; Singh & Agrawal, 2001; Wertheim & Craker, 1987). Additionally, the lowest pH value on record for rain is 2.9, so pH 3.0 is reasonable for the lowest pH value. We used deionized (DI) water as the control because our DI water had a pH value of 6.0 and falls within the national average of rain pH (5.6 to 6.2). We decided to use corn seeds instead of other types of seeds because corn made up 12% of Maryland’s cash crops in 2011, resulting in $241 million in revenue and making corn a very
important crop in Maryland. Additionally, we kept the seeds at room temperature—25°C or 75°F. We used room temperature because seeds need a minimum temperature of 10°C or 50°F to germinate effectively and tend to germinate in a shorter time with higher temperatures (Nielson, Requirements, 2010).

Based on our background information, we came up with four hypotheses, two pertaining to the average number of days corn seeds would take to germinate and two pertaining to the percentages of corn seeds that completed germination. For the averages, our null hypothesis was that we predict that there will be no significant difference in the average number of days it takes for corn seeds to complete germination when treated with any of the pH levels tested. Our alternative hypothesis was that corn seeds treated with pH 3.0, 4.0, or 5.0 simulated acid rain will take significantly longer to complete germination as compared to corn seeds treated with pH 6.0 simulated rain. For the percentages, our null hypothesis was that we predict that there will be no significant difference between the percentages of corn seeds that complete germination within a seven-day period among corn seeds treated with any of the pH levels tested. Our alternative hypothesis was that we predict that the percentage of corn seeds that complete germination in the seven-day period will be significantly greater in corn seeds treated with pH 3.0 simulated acid rain than corn seeds treated with pH 4.0 or 5.0 simulated acid rain or pH 6.0 simulated rain.

METHODS

We conducted our study between 7 July and 14 July 2013. Our location was the Compton Science Center at Frostburg State University in Frostburg, Maryland. To set up the experiment, we placed one cotton ball (100% cotton) into each well of the 6x6 Burpee planters, having 36 wells and a water trough. On top of the cotton balls, we placed one cotton round (100% cotton), pressing it down to form a cup-like shape. Next, we placed one corn seed (Southern States Sweet Corn Vegetable Seed) in the middle of the cotton round; then placed another cotton ball on top. We then created simulated acid rains of pH 3.0, 4.0, and 5.0 using deionized (DI) water and LaMotte Sulfide #2 solution, containing about 66% sulfuric acid (H₂SO₄). Each solution we created received two designated planters. Our control was plain DI water of pH 6.0, simulating average rain.

Initiating the experiment, we poured the simulated acid rains into their respective water troughs underneath the wells. Then we inserted each planter into an incubator set at 25°C (75°F). We kept the planters in the incubators for approximately seven days. Every day we checked the corn seeds to record whether the radicle root, coleoptile, and lateral roots had emerged. If the roots had emerged, we recorded the number of days it took each to emerge from the start of data collection on a grid. The data collection grids were 6x6, having 36 squares, to correspond directly with the construction of the planters to avoid marking the wrong number for the wrong seed. To observe the seeds, we removed the cotton ball at the top of each well and carefully lifted out each seed with tweezers. After observing the seed, we placed it back into its respected well and recovered the seed with the same cotton ball that it had before. After collecting the data, we performed a z-test with 95% confidence to determine significant differences between the percent of corn seeds successfully germinated among all tested pH levels. We also performed t-tests with 95% confidence to determine significant differences among the raw data of
the number of days that it took for each visible stage of germination (emergence of the radicle root, coleoptile, and lateral roots) to take place, if such statistical analyses seemed necessary.

RESULTS

Table 1 displays the average number of days that it took for corn seeds to complete a specified stage of germination when treated with the different pH levels. The average number of days it took the radicle root of the corn seeds to emerge is two (2) day between all pH levels. The average number of days it took the coleoptile of corn seeds to emerge is three (3) days between all pH levels. The average number of days it took the lateral roots of corn seeds to emerge is five (5) days between all pH levels. Since it took the same number of days for each stage to occur in all pH levels, we determined there was no significant difference between the numbers of days it takes for corn seeds to germinate when treated with various pH levels.

<table>
<thead>
<tr>
<th>pH Levels</th>
<th>Start to Radicle</th>
<th>Start to Coleoptile</th>
<th>Start to Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5.0</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4.0</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3.0</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 1 displays the percentages of corn seeds that started germination with at least the emergence of the radicle root within our seven-day data collection period. Visually, there appears to be no significant difference in these percentages because all of the percentages were within 6% of each other. A z-test comparing the percentages of corn seeds treated with pH 3.0 and corn seeds treated with pH 4.0 simulated acid rains that started germination ($p = 0.095; n = 72$), pH 3.0 to 5.0 ($p = 0.095; n = 72$), pH 3.0 to 6.0 ($p = 0.15; n = 72$), pH 4.0 to 5.0 ($p = 0.50; n = 72$), pH 4.0 to 6.0 ($p = 0.39; n = 72$), and pH 5.0 to 6.0 ($p = 0.39; n = 72$) confirmed that there is no significant difference between the percentages of corn seeds that started germination between all pH levels tested.
Figure 1. – This chart displays the percent of corn seeds that started germination, signified with the emergence of the radicle root, within a seven-day period for each pH value tested.

As Figure 2 displays, corn seeds treated with pH 5.0 or 4.0 simulated acid rain had the lowest percentage of total corn seeds germinated within the seven-day period. A z-test comparing the percentages of corn seeds that finished germination when treated with pH 4.0 simulated acid rain and pH 6.0 simulated rain ($p = 0.0051; n_1 = 65, n_2 = 66$), and pH 5.0 and 6.0 ($p = 0.0051; n_1 = 65, n_2 = 66$) confirmed significant differences between these values. Additionally, a z-test comparing the percentages of corn seeds treated with pH 3.0 simulated acid rain and those treated with pH 4.0 ($p = 0.074; n_1 = , n_2 = 65$), pH 3.0 and 4.0 ($p = 0.074; n_1 = 69, n_2 = 65$), pH 3.0 and 6.0 ($p = 0.12; n_1 = 69, n_2 = 66$), and pH 4.0 and 5.0 ($p = 0.50; n_1 = 65, n_2 = 65$) confirmed that there was no significant difference between the simulated acid rains.
CONCLUSIONS AND DISCUSSION

Our null hypothesis for the average number of days between the stages of germination was that we predict that there will be no significant difference in the average number of days it takes for corn seeds to finish germination when treated with any of the pH levels tested. We used this hypothesis to determine if simulated acid rain had any effect on how long corn seeds take to germinate. We failed to reject this null hypothesis because we determined there was no significant difference between the average numbers of days that it took for corn seeds treated with any of the pH levels tested to finish the stages of germination. As seen Table 1, each of the stages took the same number of days between each pH level tested to occur. With this conclusion, acid rain seems to not impact the time it takes for corn seeds to germinate; however, acid rain may affect other aspects of corn seed germination.

As an observation, the corn seeds treated with simulated acid rains, especially the pH 3.0 simulated acid rain, had much shorter roots than the corn seeds treated with pH 6.0 simulated rain. Shorter roots would limit the crops’ ability to acquire nutrients and water if planted and may result in the death of the crop. Accounting for our results, pH 5.0 and lower acid rain may cause a reduction in overall yield due to reduced germination of the corn seed, but pH 3.0 acid rain may not reduce yield due to poor germination. Yield reduction for farmers due to pH 3.0 acid rain may be attributed to the shorter roots, like those of the corn seeds treated with pH 3.0 simulated acid rain in our study. Additionally, not all of the corn seeds started germination, and not all of the corn seeds that started germination finished within our seven days of data collection.

Although not all of the corn seeds started germination, we determined there was no significant difference between the percentages of corn seeds that started germination with the emergence of the radicle root between all
pH levels tested, which a z-test confirmed. With this conclusion, acid rain seems to have no effect on the percentage of corn seeds that start germination.

Our null hypothesis for the percentage of corn seeds that finish germination was that we predicted that there would be no significant difference between the percentages of corn seeds that completed germination within a seven-day period among corn seeds treated with any of the simulated acid rains. We used this hypothesis to determine if simulated acid rain had any effect on how many corn seeds completed germination after starting germination. We rejected this null hypothesis because, based on our z-tests, significantly more corn seeds completed germination when treated with pH 6.0 simulated rain in the seven-day period than corn seeds treated with either pH 4.0 or 5.0 simulated acid rain.

There are a few possible explanations for our results for the percentages of corn seeds that completed germination. Corn seeds may be more able to germinate in pH levels within the national average since that is essentially what pH levels the corn seeds absorb on average. Corn seeds’ potential adaptability being more able to germinate in pH levels within the national average may explain why the corn seeds treated with pH 6.0 simulated rain had the highest percentage of germination completion, being significantly different from the percentages for pH 4.0 and 5.0. Additionally, acid rain may be able to slow down the corn seeds’ metabolism rate. The National Atmospheric Deposition Program (n.d.) said that acid rain could slow the rate of microbiological processes, metabolism being such a process in plants, which may explain why the lowest percentages of corn seeds that completed germination were for corn seeds treated with pH 4.0 or 5.0 simulated acid rain. Acid rain is also able to increase the rate of deterioration in rocks and metals (National Atmospheric Deposition Program, n.d.; USGS, 2013). Since acid rain has the capability to increase the deterioration rate of rocks and metals, acid rain may deteriorate the testa of the corn seeds, possibly making it easier for the roots and the coleoptile to emerge. It might be possible that at pH 3.0, the testa of corn seeds begins to deteriorate, therefore increasing the ability of the roots and coleoptile to emerge. The pH 3.0 simulated acid rain potentially deteriorating the testa, coupled with the possibly slower metabolism caused by the acidic solution, may explain why the percentage of completion for pH 3.0 was slightly lower than that of pH 6.0, but not significantly different. The possibly slower metabolism of the corn seeds treated with the lower pH levels may also explain the shorter roots in those corn seeds, especially in the corn seeds treated with pH 3.0 simulated acid rain, since slower metabolism may cause slower growth in the corn seeds. Soil is generally basic, but much of the soil in Maryland is acidic because of exposure to acid rain for many years. Maryland farmers buffer their soil with lime to neutralize its acidity and manage to harvest a large amount of corn, resulting in $241 million of revenue in 2011 for example. Corn seeds’ ability to germinate in the soil of farms despite the soil’s pH may explain why the corn seeds treated with simulated acid rain were still able to germinate.

We faced several limitations in our study. One limitation that we faced was our sample size. We only used 72 corn seeds per pH value when Maryland farmers harvest approximately 500,000 acres of corn every year. Additionally, we only used one type of corn—sweet corn—while there are many types of corn, making our results not generalizable for all types of corn. We also only used four pH levels—3.0, 4.0, 5.0, and 6.0. A larger variety
of pH levels could be used to show a trend as to how corn reacts to a large variety of pH levels. Time was another limitation. Some seeds had the coleoptile emerge, but failed to complete germination in the seven days of data collection, especially the corn seeds treated with pH 4.0 or 5.0 simulated acid rain. If the corn seeds had more time to germinate, then more seeds may have completed germination, which may have altered the data to where there would be no significant differences in any of the percentages of germination completion. We only had seven days to complete the experiment, and we only checked the seeds in 24-hour intervals, making the time at which the roots and coleoptile emerged general instead of specific. In addition, we did not always check the seeds every 24-hours, possibly skewing the data due to inconsistent intervals. Another limitation was a lack of training. We did not recognize roots growing on the coleoptile as definite lateral roots until the last day of data collection, possibly skewing the data.

These limitations can be avoided in several ways. A larger sample size using a wider variety of corn types and pH levels would result in a better overview of how acid rain affects corn germination and which types of corn are affected. Additionally, expanding the time at which data collection takes place and having more frequent time intervals for checking the seeds would offer more thorough results on the time it takes for seeds to germinate. Future researchers should also be more consistent with their time intervals to avoid any possible data skewing. In addition, more thorough training on identifying roots and the coleoptile would result in more accurate data.

As a result of our study, we developed a few questions that could be used in future studies. Our first question was: how does acid rain affect the length of the roots of corn seed? Throughout our experiment, we observed shorter roots on the corn seed treated with low pH simulated acid rain, especially on those treated with pH 3.0. If this question were to be answered, farmers and the scientific community alike would understand better how acid rain affects corn seed germination. Our second question was the following: how does acid rain affect the testa of the corn seed? At the beginning of the study when we reviewed our background information, some proposed that since acid rain deteriorates rock and metal, that it might also deteriorate the testa. If one answered this question, we would understand additional information about how acid rain affects corn seeds during germination. Our third question was: what is the lowest pH solution that corn seeds can be in to germinate? Since over 80% of the corn seeds completed germination in a pH 3.0 solution, we wondered if corn seeds could germinate in a lower pH value, and where germination of the corn seed stops, if it does, at lower pH levels. If this question were answered, farmers would know which pH levels to avoid or use when treating their corn crops. Our final question was: what is the effective pH of water after it has been neutralized by the buffered soil? The soil in Maryland is treated with lime to help neutralize the acidity of the rain, and we did not use soil, so the simulated acid rain was not buffered as it is in nature and on farms. By testing and answering this question, we would know how acid rain would affect real crops on farms.

Due to our data and conclusions, acid rain seems not to have an effect on the time it takes for corn seeds to germinate. However, acid rain seems to have an effect on the percentage of corn seeds that complete germination. Our data suggests that Maryland should not be an ideal location for corn farming since the corn seeds treated with pH 4.0 and 5.0 simulated acid rains had the lowest percentage of germination completion, and
Maryland’s current average pH level for precipitation is about 4.5, but Maryland farmers use various buffers to increase the pH of the soil used for farming. Using these buffers, farmers are able to neutralize the acidity of the rain and enable effective germination and corn growth. Therefore, Maryland farmers should continue buffering their soil to yield the greatest percentage of corn seeds that complete germination.
REFERENCES CITED


