Acid Precipitation and Plant Growth Lab

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May 6, 2019

Introduction

The pH factor of soil reflects a plant's acidity level, soil bacteria, dispersion of crucial nutrients, nutrient leaching, toxic elements, and soil structure, making it a major growth-limiting factor for plants all around the world. Soil pH is imperative to consider when growing plants as all plants require different acidity levels for optimal growth (Perry, 2003). Most plants achieve optimal growth within a neutral pH range - 6.0 to 7.0 - but growth may still exist outside the neutral range with signs of poor fruiting and development. Thus, a neutral soil pH level dependent on the plant would help achieve maximum height of the plant, maximum diameter of the plant stalk, and the preferred shade/color of the leaf and plant stalk of the plant. A pH that is either too high or too low than the optimal pH level of soil for that specific plant would achieve minimal height, minimal diameter, a poor shade/color, or, worse of all, a dead plant.

Purpose

The purpose of this experiment is to determine the effects of rainwater solutions with pH levels of 1, 1.5, 2, 3 and 7, and its effects on the quantitative and qualitative traits of plants, particularly plant height, plant stalk diameter, and the shade of the leaf and plant stalk.

Hypothesis

If rainwater solutions with pH levels of 1, 1.5, 2, 3 and 7 are poured on separate plants, then the plants with rainwater with pH levels less than 4 will be shorter and have a smaller stalk diameter than the plant with rainwater with a pH level of 7, because the low soil pH in those plants decreases nutrient availability and most commonly leads to aluminum toxicity. The decreased nutrient availability and aluminum toxicity will prevent the plant from growing optimally, resulting in a decreased plant height and stalk diameter. Moreover, the plants receiving rainwater with a pH level lower than 4 will have a lower leaf viridity than the plant receiving rainwater with a pH level of 7. This is because the low soil pH decreases nutrient availability, which decreases chlorophyll production, resulting in a lower leaf viridity.

Materials

- Potting Soil
- 5 Plastic Soil Pots
- 20 Beans
- Rainwater Solution of pH 1.0
- Rainwater Solution of pH 1.5
- Rainwater Solution of pH 2.0
- Rainwater Solution of pH 3.0
- Rainwater Solution of pH 7.0
- 5 500mL Beakers
- Ruler
- Watering Can
- Measuring tape
- Calculator
- Masking Tape
- Sharpie

- Large Lamp
- Camera

Procedure

1. Attach a 5 cm strip of masking tape on the side of each soil pot and label the pots as 1, 1.5, 2, 3, and 7 with a black sharpie. This represents the pH level of the rainwater that will exclusively be poured into the pots.
2. Fill each pot with potting soil, leaving 3 cm from the top of the pot.
3. Pat down the potting soil so that the soil is firm.
4. Dig a hole 5 cm deep in the soil and plant 4 beans into each pot, evenly spaced from each other and with a margin of 15 mm from the edge of the pot
5. Set up and turn on the lamp
6. Arrange the 5 pots so that each pot receives the same amount of light from the lamp
7. Measure 40 mL of rainwater solution into separate beakers
8. Pour the rainwater solutions into the pots labelled as the pH of the rainwater solution
9. Measure plant height with the measuring tape from the top of the soil to the highest part of the plant.
10. Measure stalk circumference by wrapping the part of the stalk closest to the soil.
11. Divide stalk circumference by pi to determine the stalk diameter.
12. Record the shade of green closest to the shade of green of the leaves according to the shade reference sheet.
13. Take picture of plant.
14. Repeat steps 7 - 13 for every day of the experiment.

Observations

Date	Traits	pH 1	pH 1.5	pH 2	pH 3	pH 7
April 15 Monday *(First Day)*	Shade of Leaves and Plant Stalk:	n/a	n/a	n/a	n/a	n/a
	Height (mm):	0	0	0	0	0
	Diameter of Plant Stalk (mm):	0	0	0	0	0
April 16 Tuesday	Shade of Leaves and Plant Stalk:	n/a	n/a	n/a	n/a	n/a

	Height (mm): Diameter of Plant Stalk (mm):	0 0	0 0	0 0	0 0	0 0
April 17 Wednesday	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	Dark Jungle Green 35,31,27 52 1.4	Dark Jungle Green 35,31,27 62 1.5	Dark Jungle Green 35,31,27 39 1.6	Dark Jungle Green 35,31,27 79 1.7	Dark Jungle Green 35,31,27 59 1.8
April 18 Thursday	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	34, 35, 24 56 1.4	34, 35, 27 65 1.4	33, 35, 26 42 1.6	32, 36, 25 82 1.8	37, 36, 23 68 1.9
April 19 Friday *(Good Friday)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a

April 20 Saturday	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
April 21 Sunday *(End of the First Week)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
April 22 Monday *(Start of the Second Week)* *(Easter Monday)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
April 23 Tuesday	Shade of Leaves and Plant Stalk: Height (mm):	Dollar bill 148, 179, 86 57 1.5	Medium spring bud 189, 222, 136 71 1.6	Avocado 92, 114, 19 65 1.3	Pistachio 179, 201, 109 91 1.8	Asparagus 142, 166, 86 63 1.9

	Diameter of Plant Stalk (mm):					
April 24 Wednesday	Shade of Leaves and Plant Stalk:	150, 180, 154	150, 210, 154	150, 120, 154	150, 203, 154	150, 180, 154
	Height (mm):	57	74	68	94	69
	Diameter of Plant Stalk (mm):	1.5	1.6	1.4	1.8	1.9
April 25 Thursday	Shade of Leaves and Plant Stalk:	144, 168, 125	144, 203, 125	144, 152, 125	144, 214, 125	144, 201, 125
	Height (mm):	56	79	68	96	71
	Diameter of Plant Stalk (mm):	1.3	1.7	1.4	1.8	2.0
April 26 Friday	Shade of Leaves and Plant Stalk:	160,170, 176	160,200, 176	160,167, 176	160,220, 176	160,212, 176
	Height (mm):	57	82	69	100	65
	Diameter of Plant Stalk (mm):	1.1	1.6	1.2	1.8	2.6
April 27 Saturday	Shade of Leaves and Plant	n/a	n/a	n/a	n/a	n/a

	Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a	n/a n/a	n/a n/a	n/a n/a	n/a n/a
April 28 Sunday *(End of the Second Week)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
April 29 Monday *(Start of the Third Week)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	Med spring bud 200, 232, 122 57 0.2	asparagus 135, 165, 76 81 1.6	green 107, 158, 85 74 1.0	pistachio 131, 203, 128 102 2	pistachio 151, 197, 92 63 3
April 30 Tuesday *(Ottawa Excursion)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a

	(mm):					
May 1 Wednesday *(Ottawa Excursion)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
May 2 Thursday	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	Light golden roe yellow 251 250 214 Dead Dead	Granny Smith Apple 167 225 119 94 1	Android green 152 190 71 85 1.2	pastel green 108 211 114 113 1.4	pistachio 157 208 91 82 2
May 3 Friday *(Last Day)*	Shade of Leaves and Plant Stalk: Height (mm): Diameter of Plant Stalk (mm):	Egg Shell 238, 230, 221 Dead Dead	Moss Green 179, 210, 170 85 1	Tea Green 220, 245, 205 80 1	June Bud 168, 219, 92 111 2	Green (RYB) 131, 185, 51 85 2.1

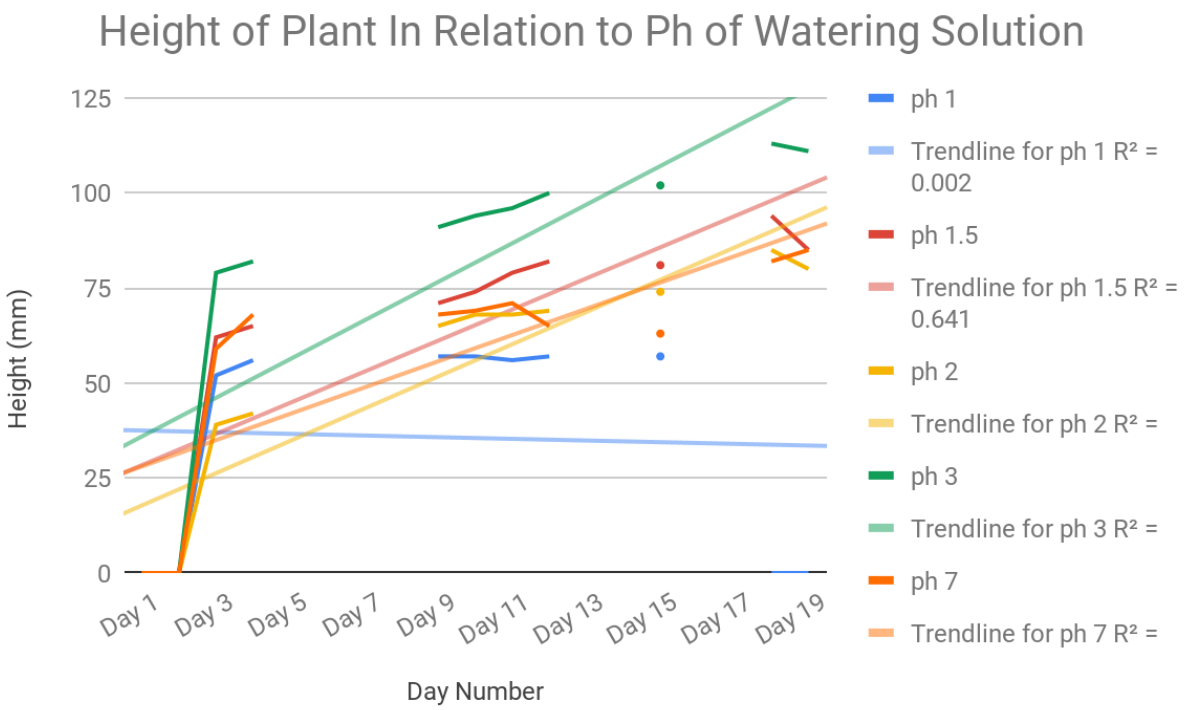
Analysis

1. **Did the results support your hypothesis? What were some sources of uncertainty or error in the experiment?**

The results of the experiment differed from the hypothesis in a few aspects. The results supported the idea that the diameter of the plant stalk of a plant with a watering solution of pH 7 would be greater than the diameter of plants with watering solutions less than pH 4. This is shown as the diameter of the stalk for pH levels less than 4 were less than 2mm, while the final stalk diameter of pH 7 was greater than 2mm. The results of the experiment also supported the fact that a plant with pH 7 is objectively more green than plants with a pH level lower than 4. Meanwhile, the results of the experiment showed that the plant with a watering solution of pH 3 grew the most in height compared to the other plants, which goes against the hypothesis. A possible source of error is the precision of the pH levels of the watering solutions. This could affect the plant growth by a significant amount. Furthermore, the pH levels of the bottles may have possibly been mistakenly mixed by the supervisor, particularly the bottle labeled pH 7 and 3, leading to inconsistent results.

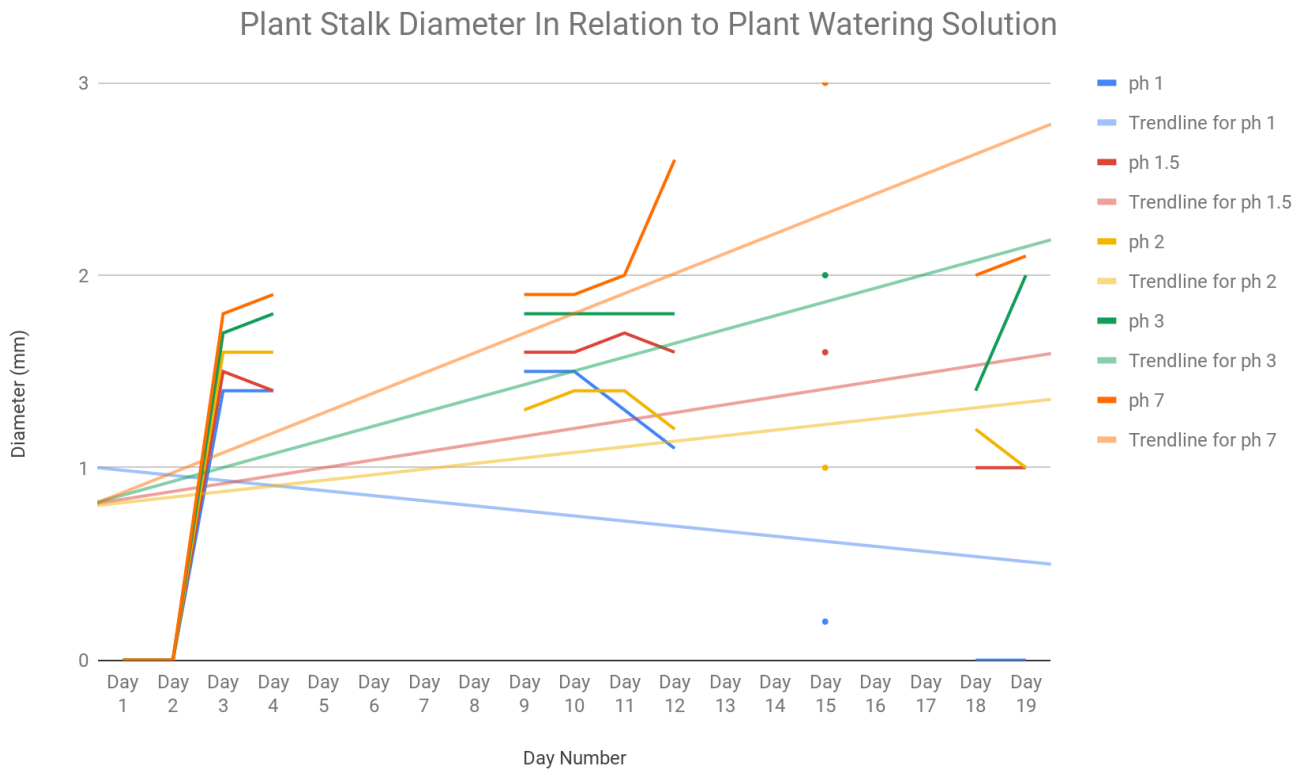
2. **Use linear regression to model the plant height against the pH solutions. How did plant height vary depending on the rainwater solution used?**

The radish plant receiving pH solutions with a pH of 1 had the lowest projected height as it had died during data collection. Surprisingly, the radish plants receiving rainwater solutions with a pH level from 1.5 to 3, inclusive, have higher projected growths than the radish plant receiving a rainwater solution with a pH level of 7. The radish plant receiving a rainwater solution with pH 3 has the highest projected growth, followed by the radish plant receiving a rainwater solution with pH 2, then the radish plant receiving a rainwater solution with pH 1.5, and finally the radish plant receiving a rainwater solution with pH 7. However, looking at the individual data points suggests that each of the radish plants except for the radish plant receiving a rainwater solution with pH 7 would decline in plant height, while the radish plant receiving a rainwater solution with pH 7 would grow to a higher height, eventually growing taller than the other plants.



3. **Use linear regression to model each pH solution and its corresponding stalk diameter. How did the acidity of the rainwater solution affect the stalk diameter?**

From the data in this experiment, a clear correlation between stalk diameter and the pH of the rainwater solution that each radish plant received; a rainwater solution with pH closer to 7 directly correlated with a higher stalk diameter. The radish plant receiving a rainwater solution with pH 7 has the highest projected stalk diameter, followed by the radish plant receiving a rainwater solution with pH 3, then the radish plant receiving a rainwater solution with pH 2, then the radish plant receiving a rainwater solution with pH 1.5, and finally, the radish plant receiving a rainwater solution with pH 1. Furthermore, the radish plants receiving rainwater solutions of pH 1, 1.5, and 2 had begun to decline in stalk diameter growth or had died, suggesting that those radish plants would continue to decline in stalk diameter growth. However, the radish plants receiving rainwater solutions of pH 3 and 7 have higher projected stalk diameters and were increasing in stalk diameter growth, suggesting that both plants would continue to grow to have wider stalks.



4. **Given the soil pH distribution of an area, how should fertilizers be chosen to encourage the soil pH to increase or decrease towards the optimal pH level?**

The primary ingredient in fertilizer that contributes to making the soil more acidic or basic is nitrogen. The key molecules containing nitrogen that could affect soil pH are the urea molecule ($CO(NH_2)_2$), ammonium (NH_3^+), and nitrate (NO_3^-), and converting nitrogen from one form into another or plant uptake of urea, ammonium, or nitrate can change the pH of the soil. Fertilizers that are ammonium-based acidify soil because they generate two hydrogen ions for each ammonium molecule that undergoes nitrification to produce nitrate. If the produced nitrate is taken up by the plants, one of the hydrogen ions will be consumed (or excretion of OH^-), thereby decreasing the soil acidity. Fertilizers based in nitrate however, can increase soil pH as a hydrogen ion is absorbed by the plant (or an OH^- is excreted) in the uptake of nitrate. To reach the optimal soil pH of 7 (as supported by the findings of this experiment), ammonium-based fertilizers should be used in areas in which the soil pH is too basic, and nitrate-based fertilizers should be used in areas in which the soil pH is too acidic.

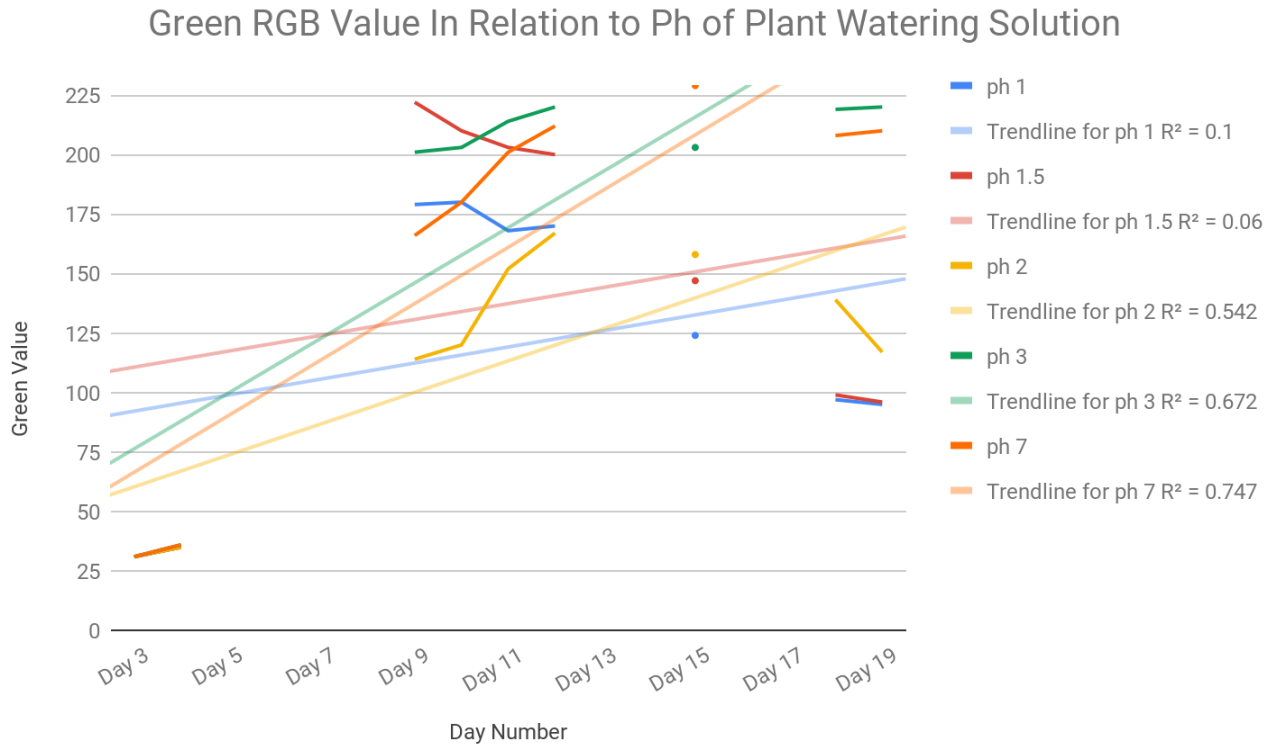
5. **Using prior knowledge and inferring from the data of this lab, predict how a watering solution above a pH level of 7 (distilled water) would affect plant growth? Would certain pH levels give the same results? For instance, would a solution of pH 1 and a solution of pH 13 give similar results?**

Considering the results and data of this lab, the ideal watering solution would have a pH level between 3 and 7. Thus, a watering solution with a pH over 7 would not benefit the plants in terms of growth in terms

of height or diameter of the stalk, although a watering solution over a pH level of 7 could potentially make the leaves of the plant more green, since the plant watered with a solution of pH achieved maximum green color in this experiment. With prior knowledge, a pH level too high or too low is detrimental to plant growth, and assuming that the ideal pH level is between 3 and 7, certain pH levels over 7 could indeed give very similar results to pH levels under 7. For example, a pH level of 1 & 14 could share similar plant heights and stalk diameters. In other words, these solutions could help achieve a dead plant. This assumption would be an interesting area to investigate in later experiments, and would also help determine the optimal pH level for optimal plant growth.

Appendix

Figure 1.1



Works Cited

Perry, Leonard. “PH for the Garden .” *PH for the Garden*, University of Vermont Extension System, 8 May 2003, pss.uvm.edu/ppp/pubs/oh34.httm.