

# The effect of simulated acid rain on growth of root systems of *Scindapsus aureus*

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## Abstract

The effect of acid rain on root systems has not been adequately studied. This study examined the effect of simulated acid rain on the root systems of a common tropical vine. Cuttings (10 cm) of *Scindapsus aureus* were grown for 7 weeks without soil in deionized water in which the pH was adjusted with sulfuric acid to 2.25, 3.26, 4.4, 5.5, and 6.5 (no acid added). Tap water (pH=8.1) was also examined. Root number and total root length were measured at baseline and after 7 weeks. Stock water at the initial pH was used to maintain the water level weekly. There were no differences in either root number or root length in any of plants in pH 4.4 or greater. Plants at the two lowest pH settings did not produce significant roots. Healthy plants (pH $\geq$ 4.4) acidified the water's pH in which they were growing to 4.4-5.4. The pH of plants in more acidic pH remained unchanged. Some roots prefer a more acidic pH. If this is characteristic is widespread, the effect of acid rain on plant root systems may be less severe than anticipated.

## Introduction

Acid rain is the decrease in pH of rain water resulting from human activity. It results from the burning of fossil fuels, releasing NO<sub>x</sub> and SO<sub>x</sub>.<sup>1</sup> When these pollutants dissolve in rain water they form nitric acid and sulfuric acid. Atmospheric SO<sub>2</sub> has increased 20 fold globally since the 1800s.<sup>2</sup>

Simulated acid rain with pH<3.0 has been shown to have deleterious effects on germination and growth of various plant species.<sup>3-5</sup> Roots can be affected, generally with reduced root growth at very low pH (<3).<sup>5,6</sup> In these experiments, plants are either grown in soil,<sup>5</sup> or are germinated from seed.<sup>6</sup> The effect of simulated acid rain on plant cuttings has not been previously studied.

In the current study we chose to examine the effect of a component of acid rain, sulfuric acid, on plant cuttings. We did this so that we

could directly examine root growth, which we could do without disturbing the plant. Additionally, cuttings are an injured plant, and since injuries are common in nature, this allowed us to examine the effect of acid rain on root growth of an injured plant. Both of these have not been previously done.

## Materials and Methods

Four experimental pHs (2.25, 3.26, 4.4, and 5.5), and two control pHs (6.5 no acid added to deionized water and 8.1 local tap water) were examined. To reduce the number of variables introduced in this experiment, only sulfuric acid was used to simulate acid rain, rather than a combination of both sulfuric acid and nitric acid. Sulfuric acid was added to deionized water to create stock pH-adjusted water which was made in one initial batch, and was used to water the plants for the duration of the experiment. Stock water, a large amount of water adjusted to the desired pH, was used to top-off the plants' water source, so that the pH would not change over time due to evaporation or dilution with addition of deionized water. Deionized water was used in the experiments because rain is essentially made of distilled water; many chemicals are added to tap water that are not found in rain and can react with sulfuric acid. However, we utilized a tap water control because deionized water also deprives cuttings of needed minerals, and we were concerned that the mineral deficiency would adversely effect the experiment.

Cuttings of the money plant, *Scindapsus aureus*, were utilized. This plant was used because it does well when cut. Healthy mature plants were the source of 10 cm cuttings. Cuttings were placed in 15 cc plastic tubes in each of the experimental pH solutions. All experiments were performed in triplicate.

The total number of new roots (both primary and secondary), and the total length of the root system was recorded weekly for 7 weeks, but the primary outcome measure was the final measures. Student t-test was used to compare all the results at week 7.

## Results

Nearly all cuttings in pH $\geq$ 4.4 sprouted roots (with the exception of one cutting in pH 6.5). The number (Figure 1A) and cumulative length (Figure 1B) of these roots was not significantly different in any of the pH $\geq$ 4.4. No roots sprouted in the most acidic solution (pH=2.25), and an average of only 2 roots/plant sprouted in those growing in pH=3.26 (Figure 1A). There was no significant growth of the stem or the leaves of

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any of the plants. Plants growing at less acidic pHs acidified their growing water to a range of 4.4-5.4 (Table 1). Plants in the two most acidic pHs did not alter their waters' pH (Table 1). In one cutting at pH of 6.5 in which no roots sprouted, the water remained at a pH of 6.5.

## Discussion and Conclusions

*S. aureus* cuttings exposed to simulated acid rain in the pH range of 4.4-8.1 showed no differences in root germination and growth (Figure 1). There were no significant stem or leaf growth in any of the plants in this brief study. Cuttings exposed to pH $\leq$ 3.26 did poorly with no or minimal root growth and deterioration of the existing leaf growth. While this study utilized a tropical vine, other investigators have noted that plants generally do well when exposed to simulated acid rain pH $\geq$ 4.<sup>3-5</sup> Corn (*Zea mays*) or *Eucalyptus* seedlings experience a promotion of root growth at pH of 4.5 compared to 6.5.<sup>7,8</sup> These data may be relevant

Table 1. The pH of the water used to treat *S. aureus* cuttings. The original pH is the pH of the water added to the plant vessel, the ending pH is the pH of the water in which the plant grew.

Original pH	Ending pH
2.25	2.3
3.26	3.3
4.4	4.4
5.5	5.4
6.5	4.4
8.1	4.6

to the study of acid rain since the average pH of acid rain in the eastern United States in 2007 is approximately 4.4.<sup>9</sup> This rain water pH is an improvement that is due to reduction of SO<sub>x</sub> emissions,<sup>1</sup> but the problem continues. While the current study, and several others,<sup>3-5,7,8</sup> suggests that the roots of many flowering plants may be able to tolerate the current level of acid rain, acid rain has been shown to be quite destructive, particularly to aquatic environments.<sup>1,10</sup>

*S. aureus* cuttings may actually prefer mildly acidic environments. Plants placed in less acidic, or basic environments, acidified their water environment to approximately pH of 5 (Table 1). This appeared to be an active process of the roots, since the one cutting at 6.5 that did not germinate roots, did not alter final pH. Roots of plants are known to secrete hydrogen ions,<sup>11,12</sup> and this is sufficient to dissolve calcium carbonate in limestone rocks.<sup>13</sup> Simulated acid rain has been shown to inhibit proton extrusion by roots.<sup>14</sup> There are several physiological constraints that promote proton extrusion, but nutrient deficiency is most relevant to current design.<sup>13</sup>

Environmental iron and phosphate deficiency induce acid secretion by plant roots.<sup>13</sup> Most of the cuttings in the current study were placed in deionized water – a nutrient poor environment.

The current study has several shortcomings. The most important of which is the use of *S. aureus*. This tropical vine has advantages for laboratory study, but is not reflective of North American flora. Consequently, generalization of the findings is somewhat limited. However, other researchers have reported similar findings with different flowering plants,<sup>3-6</sup> suggesting the pH sensitivity and preference described herein may be a common characteristic of many plants. Additionally, the current study used cuttings placed in water. This design allows for ease of investigation of roots, but is not reflective of plants growing in soil.

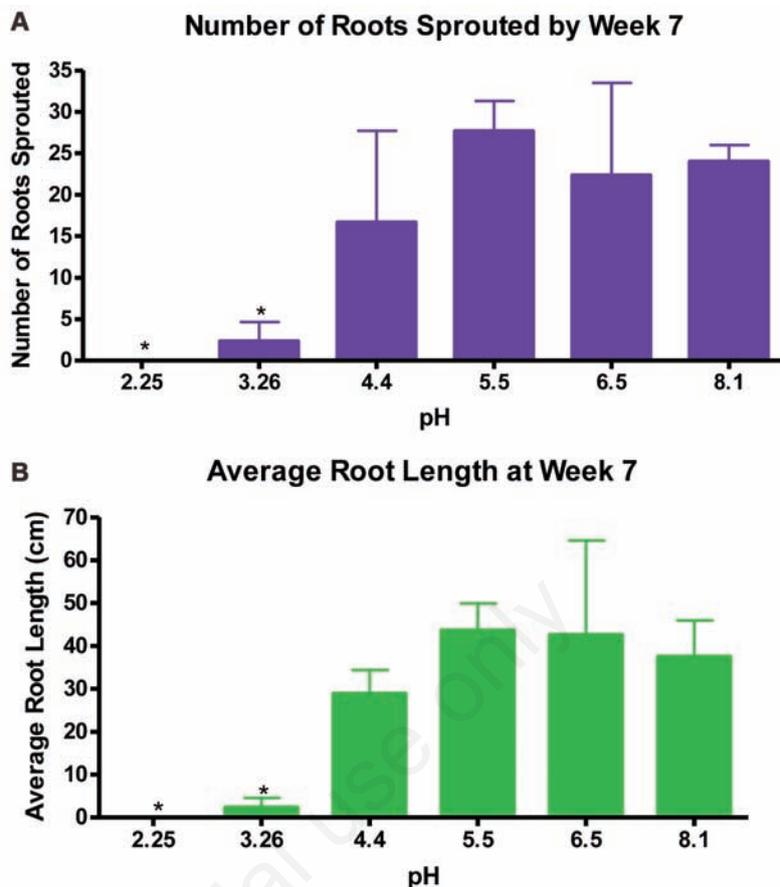


Figure 1. A) The average number of roots sprouted by cuttings of *S. aureus* cuttings as a function of the pH of the water after 7 weeks. B) The average cumulative root length of *S. aureus* cuttings as a function of the pH of the water after 7 weeks. \* $P < 0.05$  versus all other pH except 2.25 and 3.26.

We also did not investigate how the plants acidified their growing water when the pH was  $>5$ . We are unable to comment as to the mechanism by which this happened. Finally, the simulated acid rain was created with sulfuric acid, but now much of the acid rain is generated from nitric acid.<sup>15</sup>

Despite these shortcomings, the current study indicates that the root system of *S. aureus* thrives in moderate pH environments, including those that simulate current levels of acid rain in the eastern United States (pH 4.4-8.1). However, more acidic environments, as might occur in a highly polluted areas (pH 2.3-3.3), inhibit root germination and growth. *S. aureus*, like many other plants, acidify their root environment.

## References

- Singh A, Agrawal M. Acid rain and its ecological consequences. *J Environ Biol* 2008;29:15-24.
- Lehmann J, Solomon D, Zhao FJ, McGrath SP. Atmospheric SO<sub>2</sub> emissions since the late 1800s change organic sulfur forms in humic substance extracts of soils. *Environ Sci Technol* 2008;42:3550-5.
- Balasubramanian G, Udayasoorian C, Prabu PC. Effects of short term exposure of simulated acid rain on the growth of *Acacia nilotica*. *J Trop Forest Sci* 2007; 19:198-206.
- Manisha Singh L, Singh SP. Studies of pH levels of simulated acid rain on *Phaseolus radiatus* CVS. PS-16 and K-851. *Biochem Cell Arch* 2008;8:105-7.
- Yoon JH, Lee DH, Woo KS. Effects of simulated acid rain on above- and below-ground growth of *Liliodendron tulipifera* L. seedlings. *J Kor Forest Soc* 2008;97:204-14.
- Sirohi DS, Khan MAA. Effects of atmospheric pollution as acid rain on growth, chlorophyll content and root nodules of *Trifolium alexandrinum* L. *Crop Res (Hisar)* 2006;32:528-34.
- Aggangan NS, Dell B, Malajczuk N. Effects of soil pH on ectomycorrhizal response of *Eucalyptus urophylla* seedlings. *New Phytologist* 1996;134:539-46.

8. Hasenstein KH, Evans ML. The influence of calcium and pH on growth in primary roots of *Zea mays*. *Physiol Plant* 1988;72: 466-70.
9. National Atmospheric Deposition Program. 2007 annual summary. Available from: <http://nadp.sws.uiuc.edu/lib/data/2007as.pdf>
10. Veron JEN. Mass extinctions and ocean acidification: biological constrains on geological dilemmas. *Coral Reefs* 2008;27:459-72.
11. Mengel K, Schubert S. Active extrusion of protons into deionized water by roots of intact maize plants. *Plant Physiol* 1985; 79:344-8.
12. Römheld V, Müller C, Marschner H. Localization and capacity of proton pumps in roots of intact sunflower plants. *Plant Physiol* 1984;76:603-6.
13. Hinsinger P, Plassard C, Tang C, Jaillard B. Origins of root-mediated pH changes in the rhizosphere and their responses to environmental constraints: a review. *Plant Soil* 2003;248:43-59.
14. Li YH, Yan CL. Responses of the plasma membrane ion-pumping activities of *Casuarina equiseti folia* seedling twigs to acid rain. *Xiamen Daxue Xuebao (Ziran Kexue Ban)* 2006;45:131-5. Available from: <http://www.dissertationtopic.net/doc/1579105>
15. Aikawa M, Hiraki T, Eiho J. Study on the acidification and pollution of precipitation based on a data set collected on a 0,5 mm precipitation basis. *Atmos Environ* 2008; 42:7043-9.

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