Development of automated sensors to track pH changes elicited by iron deficiency in hydroponic cultures

Plant Sciences
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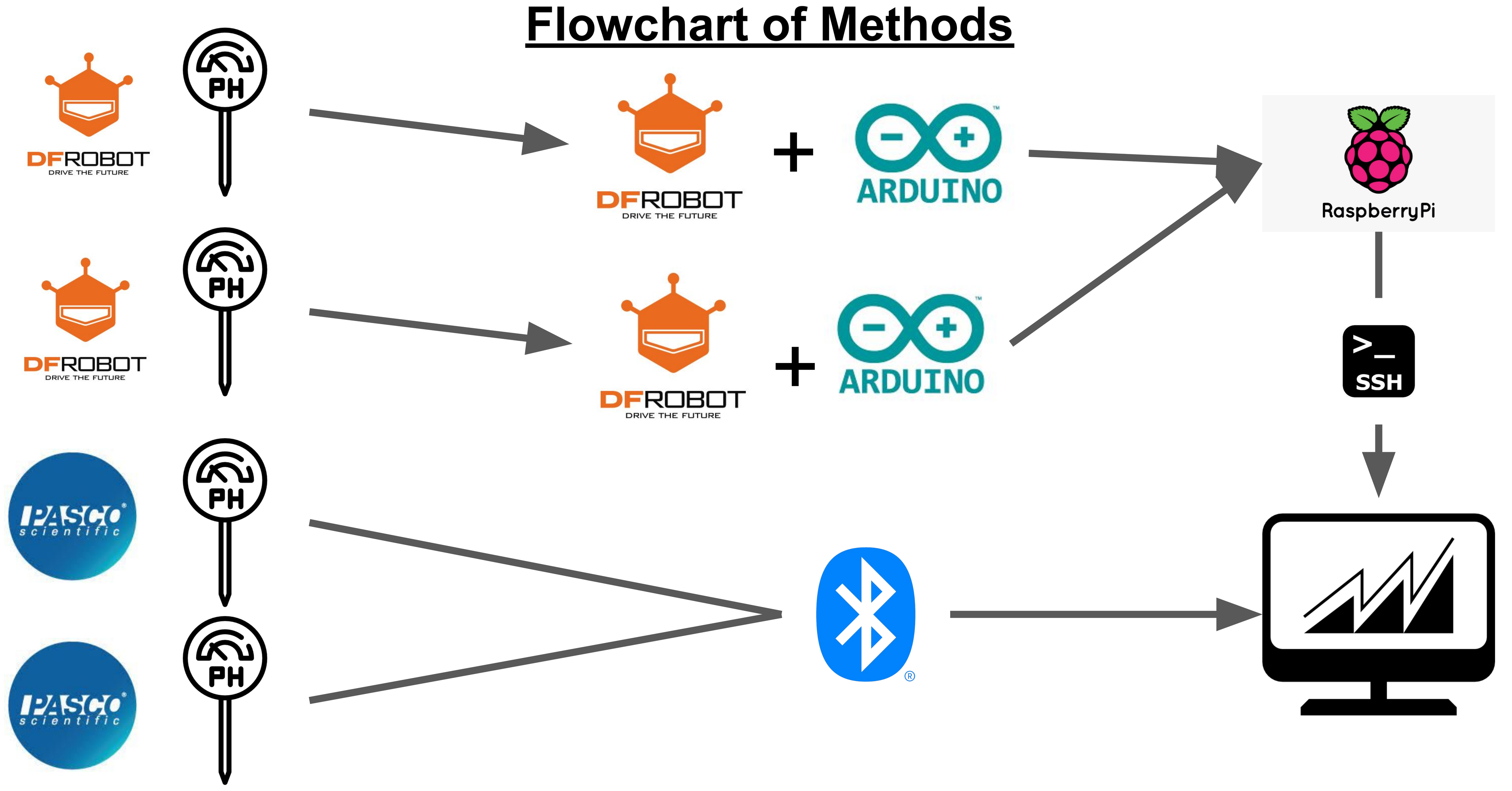
Background

Iron is an essential nutrient for plant growth. From published research, it is known that plants acidify the media under minus iron conditions. Currently, there is a lack of data that tracks the development of this phenomenon. In response, we have implemented an automated pH tracking system to record maize plants acidifying the media with and without iron over the course of one week. PASCO's Wireless pH Sensor and DFRobot Gravity pH Meter Pro sensors were both implemented and their accuracy and consistency was compared. By running this experiment on maize, we expect this pH tracking setup to be able to be replicated on any plant like *Arabidopsis thaliana*.

Objective

Demonstrate how our automated pH sensor system was able to track the acidification of the hydroponic solution caused by iron deficiency, and compare implementations of two pH sensor brands.

Flowchart of Methods



'image: Flaticon.com

For further explanation, see LusardiAndWalter video

Methods

- The control group consisted of two maize plants grown in replete hydroponic solution.
  - A PASCO sensor was placed in mutant type B73 and a DFRobot Gravity pH Meter Pro was placed in mutant type Mo17.
- Two maize plants were grown in minus iron hydroponic solution.
  - Similar to the control group, a PASCO sensor was placed in B73 and a DFRobot Gravity pH Meter Pro sensor was placed in Mo17
- PH readings are logged about every 5 minutes..
- PASCO sensors log data to the sensor itself. When a computer is reconnected with them, the data is downloaded as a comma-separated-value (csv) file.
- DFRobot sensors send data to a Raspberry Pi which formats it as a csv file. This file is downloaded when a computer is connected to the Raspberry Pi.
- The csv files are interpreted by the RShiny app as a graph showing the change in pH over the course of the experiment.

Results

Figure 1A

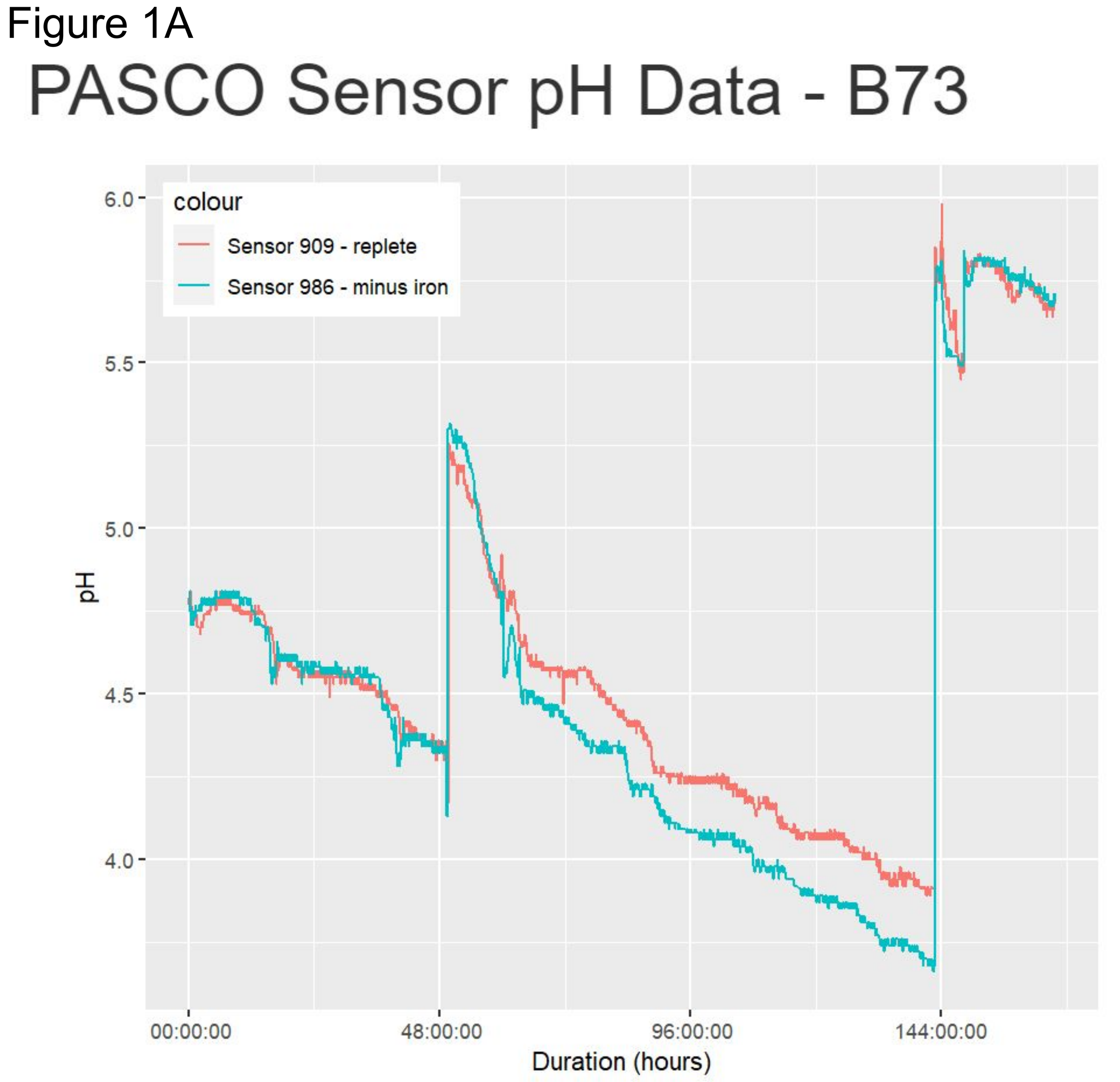


Figure 1A Pasco Sensor pH data: Over time, the maize grown in the minus iron hydroponic solution showed a lower pH compared to the maize grown in replete solution. Jumps in the data are where solution was changed.

Figure 1B

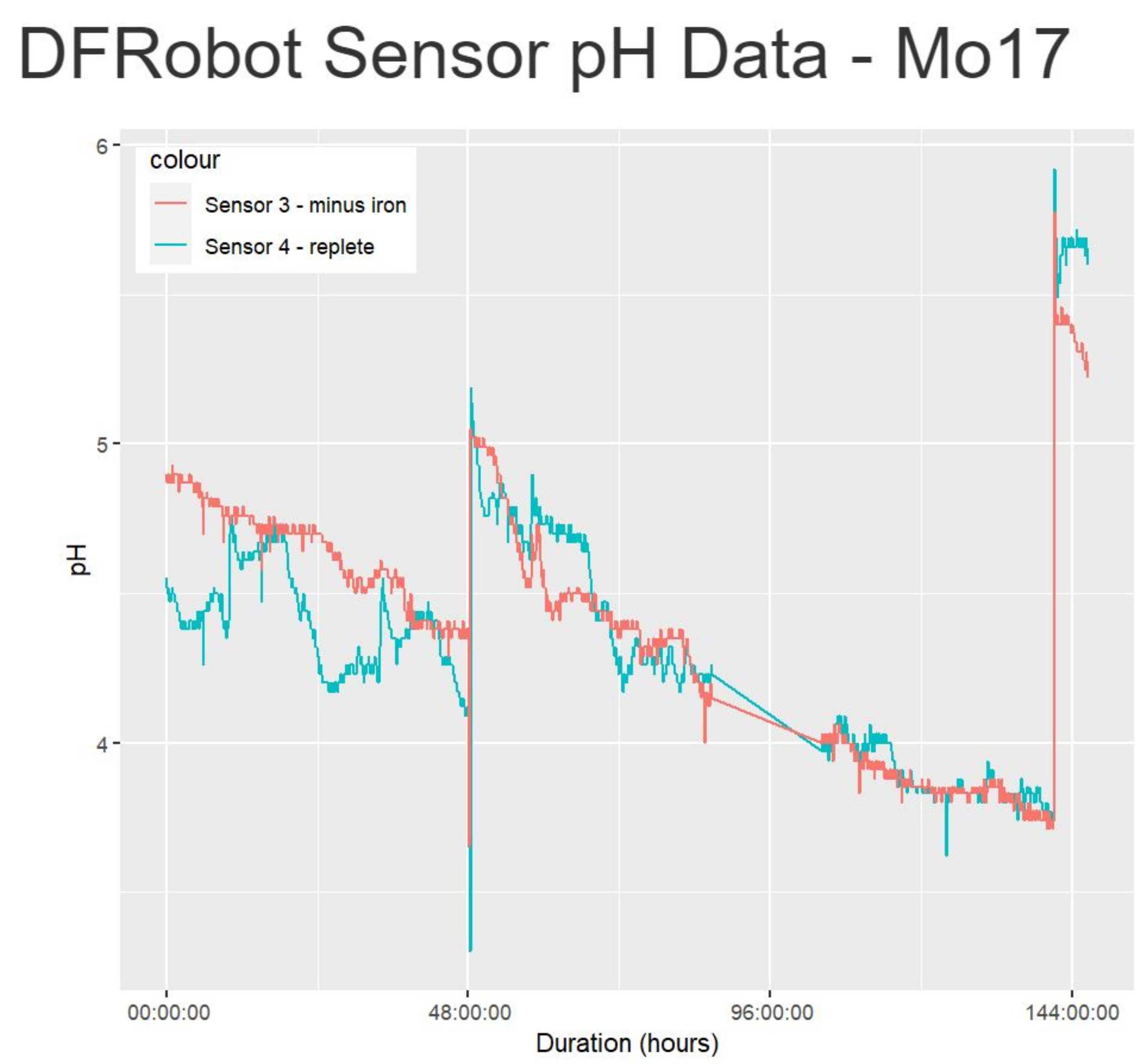


Figure 1B DFRobot Sensor pH data: The difference in pH between the minus iron and replete solution is less clear in this data, though it does show a downward trend. The data is also less consistent.

Figure 2A and 2B

Figure 2A and 2B Maize Setup: 4 total maize plants were grown hydroponically in a growth chamber. A cutout on the lid of the canister containing the hydroponic solution allowed the pH sensor to rest in the solution to take continuous data. 2B shows the electronics setup for the DFRobot sensors. See video LusardiAndWalter for more details.

Figure 2C and 2D

Figure 2B and 2C Arabidopsis Setup: *Arabidopsis* plants were grown in a trio for each hydroponic solution container. Given the small size of the plants, there needed to be enough root biomass for the sensors detect changes in media pH to record.

Conclusion

Of the two brands of pH sensors, PASCO had more consistent readings and required little setup. DFRobot sensors had more variance in their readings. However, because they are open source, the user can program additional features, such as real-time data uploads. Both sensors recorded the acidification of the media, but the PASCO sensors showed the difference between the repete and minus iron solutions more clearly. Due to time constraints, the same experiment was not able to be replicated on the plant *Arabidopsis*. Future experiments will center on accessing data in real time using a different model plant.

Acknowledgments

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