Using Images to Quantitatively Detect Plant Growth Based on IAA and Gibberellin Hormones in Increasing Agricultural Productivity

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OBJECTIVE

Monitoring plant growth using images has become an increasing trend in the agricultural industry[1]; however, the methodology used to determine plant growth is not yet established. The purpose of this project was to examine whether we can quantitatively determine different phases of plant growth and then investigate whether these quantitative plant growth can be identified using the images taken from the plants.

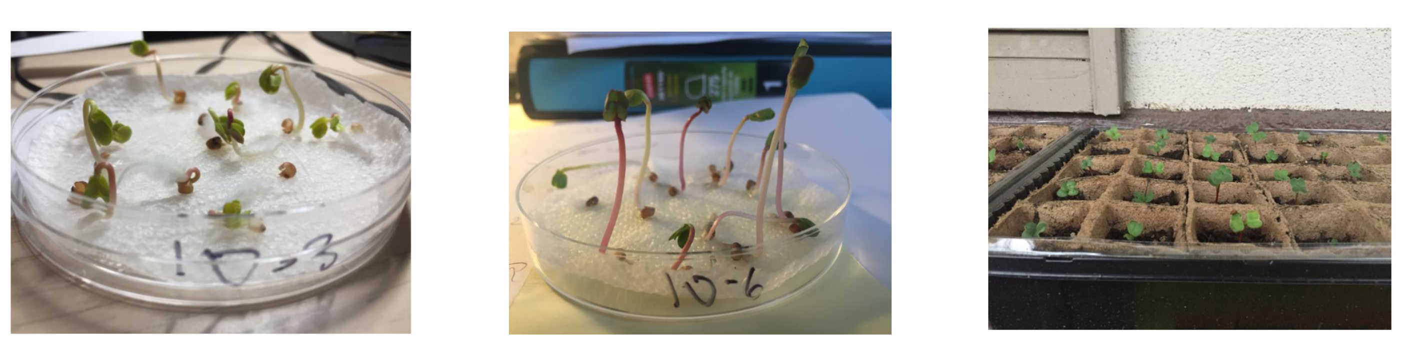
METHODS AND MATERIALS

MATERIALS

200 radish seeds, 4 Greenhouse (each containing 50 pots), 5 grams of IAA, Graduated cylinder, 10 grams of Gibberellin, 16 Petri Dishes, 6 bottles, a bottle of isopropyl alcohol, ⅛ and ¼ teaspoons, a measuring tablespoons, 8 sheets of towels, water, and Potting Mix.

METHODS

According to a study by Zhao, 2014 [1],higher molar concentrations of plant hormones increase the growth of plants by stimulating better seed germination. To examine the validity of their study, I tested two plant hormones, Indole-3-acetic acid (IAA) and Gibberellin (GA3), on the growth of cherry belle radishes.



Day 2 Day 5 Day 11

Fig.1 Experiments for the growth of cherry belle radish in three different days. Starting on Day 2, we can observe the tiny seedlings germinating from their seeds. Three days later, on Day 5, the cherry belle radishes grew tall. Later, I moved the seedlings from the Petri Dishes into pots to further grow, as shown on Day 11

I created eight different molar concentrations, four for IAA (0, 10^-4, 10^-6, 10^-8) and four for Gibberellin (0, 10^-3, 10^-5, 10^-7) using plant hormones, graduated cylinders, measuring teaspoons, and water. Then I placed paper towels onto Petri dishes, planted 13 cherry belle radish seeds on each of them, and moistened it with different plant hormone solutions. The plant growths on Day 2, Day 5 and Day11 are shown in Fig. 1. Then the number of seeds germinated from each hormone group was recorded for three consecutive days to test whether we can build the plant growth quantitatively.

To obtain the images of plants, I transferred the IAA and Gibberellin seedlings from the Petri dishes to small pots on the day six, and then an IPhone 6 was used to take pictures of plants from each hormone group on the Day 15 and Day 18. Afterwards, a Python code was implemented to allow us to pick up the red, green, and blue (RGB) values of image pixels on the plant leaves. Data were then analyzed and used to investigate whether there is any correlation between RGB values of images and the molar concentrations of plant hormones.

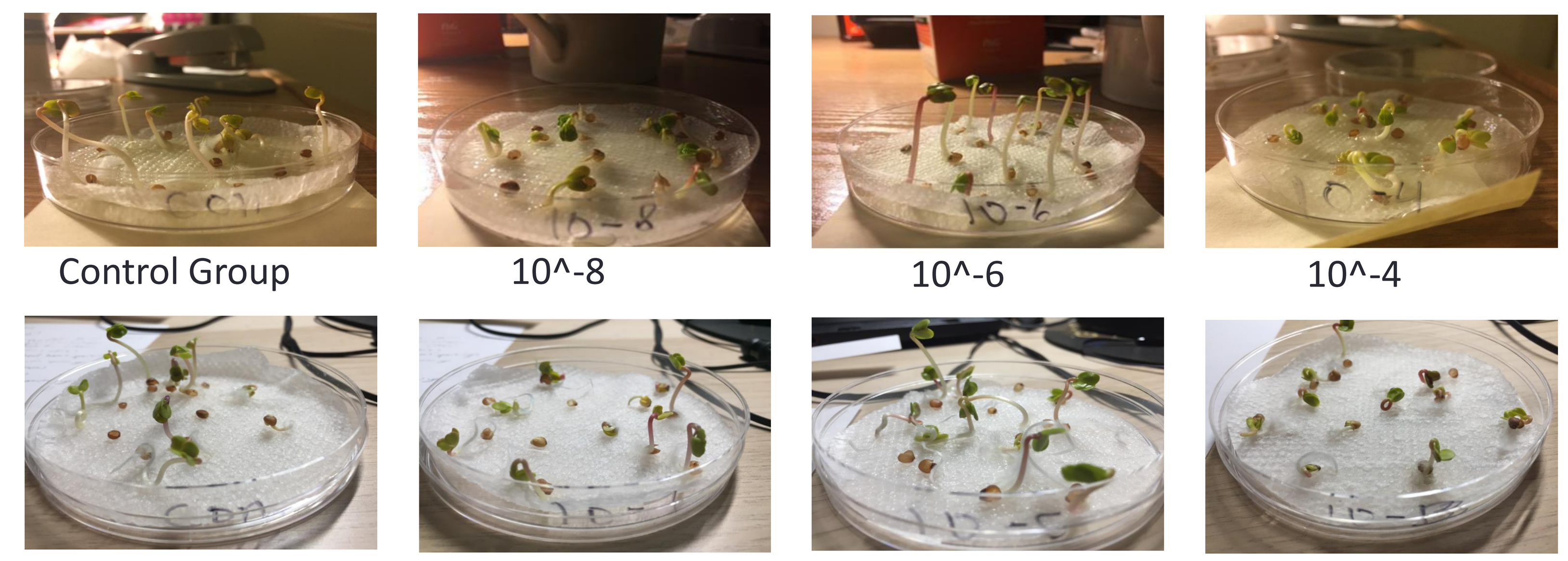
[1] Zhao, G., Jiang, X.. Roles of Gibberellin and Auxin in Promoting Seed Germination and Seedling Vigor in Pinusmassoniana. Forest Science 2014, 60(2):367–373

[2] Vasseur, F., Bresson, J., Wang, G. *et al.* Image-based methods for phenotyping growth dynamics and fitness components in *Arabidopsis thaliana*. *Plant Methods* 14, 63 (2018). https://doi.org/10.1186/s13007-018-0331-6

RESULTS

SEED GERMINATION

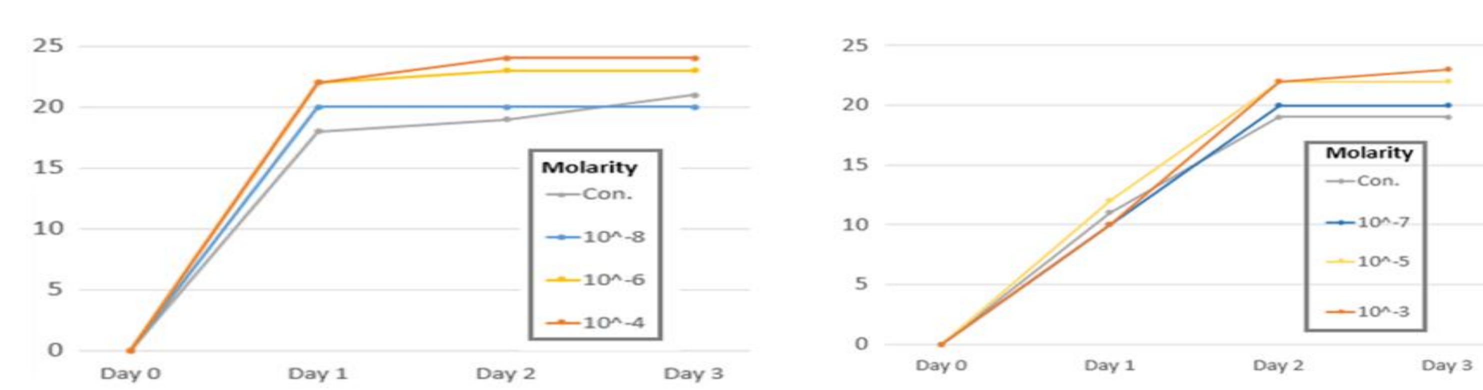
Gibberellin



A: Control Group 10^-8 10^-6 10^-4

B: Control group 10^-7 10^-5 10^-3

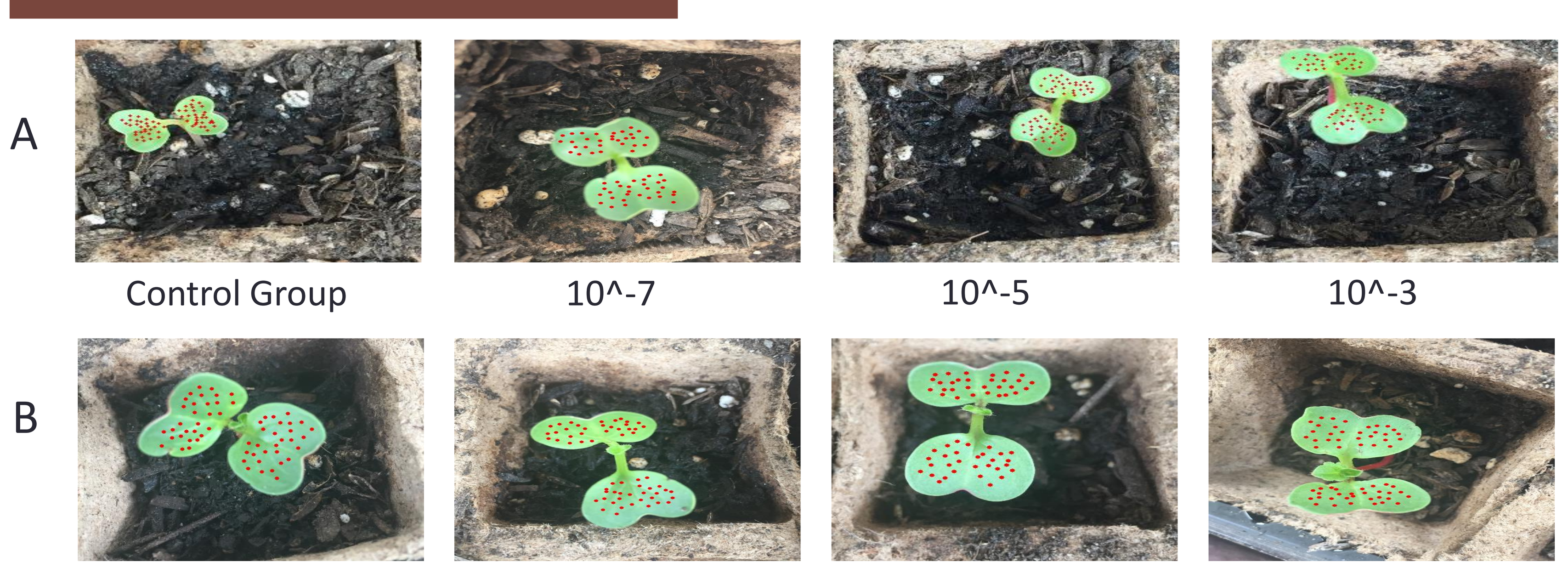
Fig.2 Test on seed germination for groups of hormone IAA (A) and Gibberellin (B). (A) The top four pictures show the seed germination results of cherry belle radishes from the IAA hormone at molar concentrations of 0, 10^-4, 10^-6, and 10^-8. (B) The bottom four pictures show the other seed germination results from Gibberellin hormone at molar concentrations of 0, 10^-3, 10^-5, and 10^-7. As the molar concentrations increased images for both (A) and (B) from left to right, the number of seeds germinated also increases. For example, the 10^-4 M group from IAA had 12 seeds germinated while the corresponding 10^-6 M group had only 10 seeds germinated.



IAA Gibberellin

Fig 3 Quantitative analysis on seed germination. The left graph shows the number of seeds germinated from three consecutive days for all four IAA groups. The right graph shows the number of seeds germinated for all four Gibberellin groups. It is clear from the graphs that higher molar concentrations of plant hormones produce better seed germination.

RGB VALUE TEST

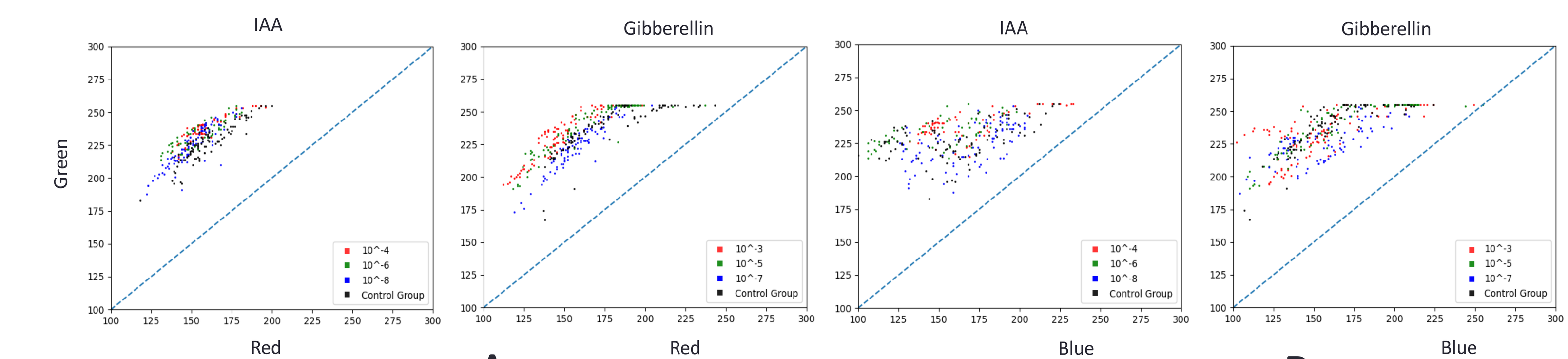


A: Control Group 10^-7 10^-5 10^-3

B: Control Group 10^-8 10^-6 10^-4

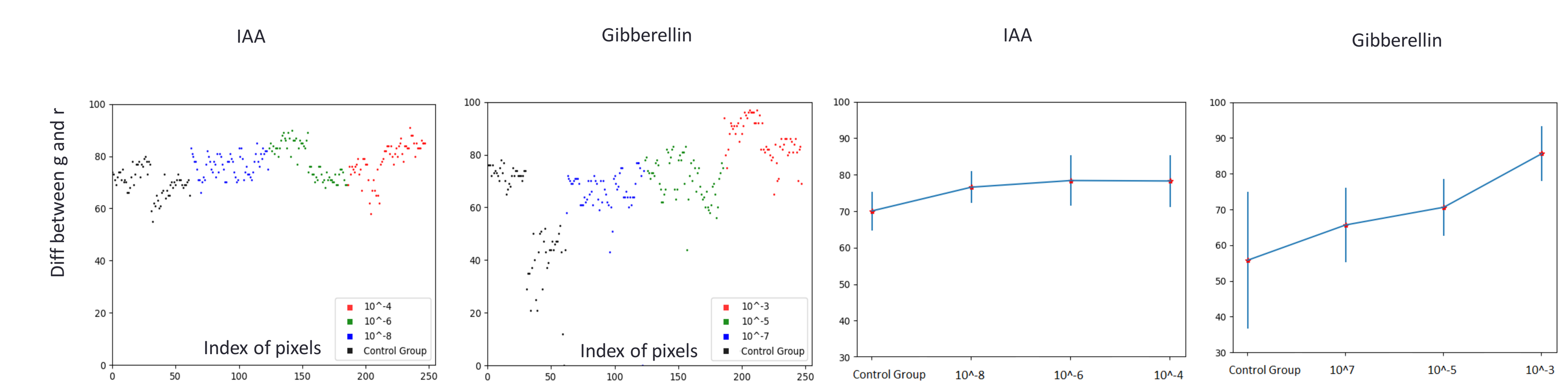
Fig.4 Pictures of plant radish leaves from groups of hormone IAA (A) and Gibberellin (B). (A) The top four pictures (A) show the plant leaves of four groups from IAA hormone at molar concentrations of 0, 10^-4, 10^-6, and 10^-8, and the red dots show the positions I clicked to investigate the correlation between RGB values of image pixels and the molar concentrations of IAA hormone. (B) the bottom four pictures show the plant leaves of four groups from Gibberellin hormone at molar concentrations of 0, 10^-3, 10^-5, and 10^-7, and the clicking positions of the leaves.

To obtain the RGB values of image pixels from the plant leaves, I implemented a Python code to allow me to conveniently loop through many images and automatically saving and loading data for analysis. Two leaves per image were selected during the test for each molar concentration group, and each leaf was clicked 30 times for RGB data collection.



A B

Fig.5 Distributions of the RGB values of the plant images using green-red (A) and green-blue (B) from four molar concentration groups for both IAA and Gibberellin hormones. (A) shows the relationship between the red and green values of image pixels from four different molar concentrations, which are indicated by different colors as shown in the legend, for both hormone IAA (left) and hormone Gibberellin (right). (B) shows similar data, but using the relationship between the blue values and green values. The plot from green-red pixels represents better groups of different molar concentrations than the plot from green-blue pixels, because we observed clearer boundaries.



A B

Fig. 6 The raw data (A) and mean ± std (B) of green value minus red values of image pixels on four different molar concentration groups for both hormone IAA and Gibberellin. I used the difference between green and red values as the indicator for different groups, which also help eliminate the bias in the images from the light brightness. (A) shows the raw distributions of the green and red difference from four groups for hormone IAA (left) and Gibberellin (right). Each group contains sixty pixels, and different groups are represented in different colors. (B) shows the corresponding mean and standard deviation of the data from (A).

Based on the mean value of the green and red differences, I also calculate the correlation coefficient, which is 0.868 for hormone IAA, and 0.981 for hormone Gibberellin, showing a strong correlation between the image features and molar concentrations of plant hormones, or a strong correlation between the image features and the quantitative plant health.

CONCLUSIONS

We did two experiments. The first experiment is the seed germination. Our data showed that as the molar concentrations of two plant hormones, IAA and Gibberellin, increased, better the rate of seed germination was achieved, indicating we can quantitatively build different phases of plant growth.

The second experiment is based on the green-red difference of image pixels of plant leaves, and a strong correlation was found between the green-red differences and the level of molar concentrations. The correlation coefficients are 0.868 for IAA and 0.981 for Gibberellin, demonstrating we can use image features to detect the different molar concentration, or to quantitatively monitor the plant growth.

Both experiments were successful, however, there are still places I can improve in the future. First, I only used the plant radish here, and it is better if the study can be extended into other plants; Second, I used only the seed germination test here, and it is preferred that the other tests from plants can be added into. Third, I only used the difference between the green and red values here, but it should be better if other image features are also included as our test indicator.

This study demonstrated a big potential for the agricultural industry to use images to quantitatively monitor the growth of plants for better plant productivity and economic benefits.