Coupled Oscillations in Plant Shoots

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Introduction

In the early time of plant growth, the sprouts will have a small vertical growth rate. However, when one of the sprouts starts oscillating in a horizontal direction, the other sprouts will also oscillate. This effect also increases the vertical growth rate suddenly. In this poster, we show the experimental result of the sprouts' behavior by putting them in one straight line and a square. In a straight line result, we find out that the sprouts only oscillate in one direction, which shows that the oscillation comes from synchronization instead of nature noise.

Figure 1: Snap shoot of the experiment.

Setup

Automatic environment control system

We install environmental control system to reduce any possible interference from outside, which including temperature control, light sensor, automatic watering system and soil moisture sensor. All of the devices were operating automatically which were control via computer.

Camera

In addition the data from the sensors, we also place three camera with different orientation for tracking and reconstruct the 3D motion of plants during the three-day period of the experiment.

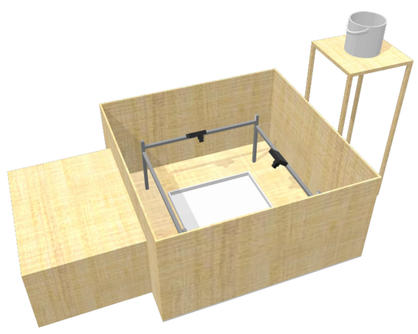

Figure 2: Schematic diagram of experiment setup.

3D Reconstruction

3D reconstruction of the shoot tips motion

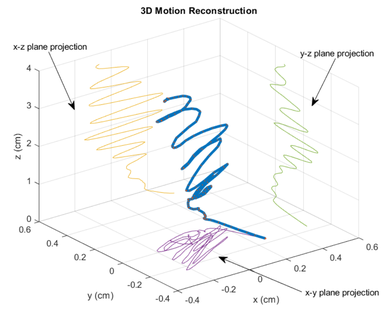

Figure 3: 3D reconstruction of shoot tip motion of a single plant and it's projection on x-y, y-z and x-z planes.

We use three camera with different angle to obtain and reconstruct the 3D motion of the shoot tips. In Figure 3 we show that the trajectory of the shoot tip started from germination to the beginning growth of leaf. We can clearly see that the oscillating motion is dominate in x-y plane compare to y-z plane, the reason is that we single out this plant from a linear array of plants which we plant them in x-direction. From Figure 4 we demonstrate that the motion of linear array of plants were govern by the whereabouts of the nearby plants for which plays an important role for coupled oscillation and synchronization.

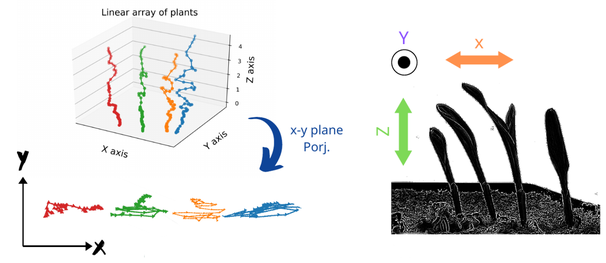

Figure 4: Shoot tips motion of linear array plants and their projection on the x-y plane (left). The real snap shoot of the plants during the experiment (right).

Collective movement

Using 3D reconstruction we can now separate the motion into horizontal motion at which we place our plants (placing in a linear array) and vertical motion.

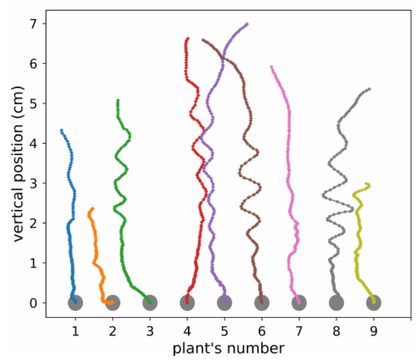

Figure 5: The trajectories of plants' shoot tip in the x-z plane in 100 hr. The distance between each plant were $1\mathrm{cm}$ in length

Vertical motion

When several plant seeding place in adjacent, they exhibit a collective acceleration of growth in the vertical direction (Figure 6). Furthermore, it appears that the plant in the center of the array grows surprisingly fast compare to the outer plant despite the fact that the outer plants have less competitor regarding of the nutrition and water.

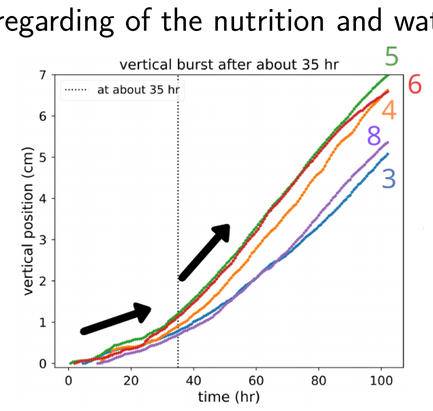

Figure 6: Collective acceleration of growth with nearby plants in the vertical direction.

Horizontal motion

If we look at the horizontal motion it oscillate with nearby plants in a collective manner. The synchronized oscillation started around 35 hr after the start of experiment and reached the peak at around 65 hr, finally stop oscillate after the appearance of plants' leaf.

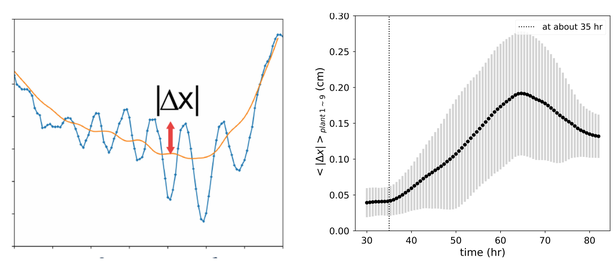

Table 1: Collective oscillation with nearby plants in the horizontal direction. We measure the $|\Delta x|$ of all plants as show in the left figure, and all the plants began to oscillate at about 35hr after the start of experiment (right figure).

Coupled oscillation

As you may observed from previous figure and of course the title of this poster, the motion of shoot tips evince coupling oscillations, especially "In phase" oscillations. As you can see from Figure 7, neighboring plants started without synchronized but gradually set off into in phase oscillations.

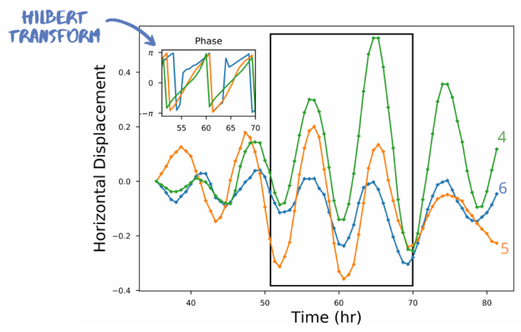

Figure 7: Horizontal coupled oscillation in adjacent plants.

Dynamic time warping

Sometimes oscillation didn't happened in an obvious way, instead they both have similar irregular movement. In order to still measure their influence and interaction with close by plant, we use dynamic warping distance to represent their similarity of motion. The astonishing thing is that from Figure 8 we identified that the grater the separation was, the more uncorrelated it became.

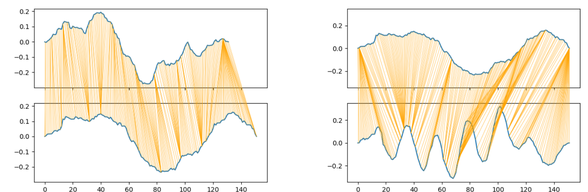

Table 2: Left figure has smaller warping distance since it has greater correlation between top and bottom data. On the contrast, the right figure has a larger warping distance.

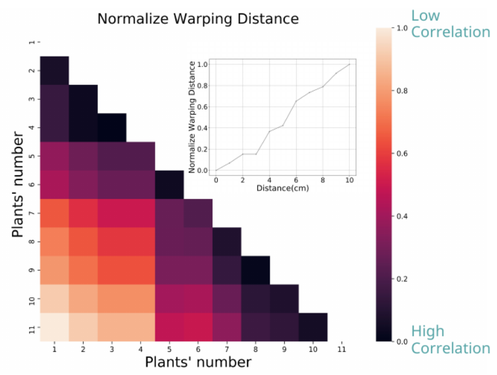

Figure 8: Horizontal coupled oscillation in adjacent plants.

Conclusion

Our experiment has show that the collective growth and coupled oscillations are emanate from the influence of adjacent plants, and their interaction weaker as the distance of separation increase.

References

[1] F. B. . S. M. Marzena Ciszak, Elisa Masi, "Plant shoots exhibit synchronized oscillatory motions," *Communicative Integrative Biology*, 2016.

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