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The Effects of Agitation Upon Plant Anatomy in Phaseolus vulgaris

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Introduction

The leaves of the plant *C. sinensis* are a treasured commodity to those who consume tea on a regular basis for its sweet taste and antioxidative properties. Tea, a pillar in European life, is gaining popularity in the US with exotic tea stores like Teavana providing a demand for high quality tea leaves. Japan is one of the leading exporters of tea to the United States. As such they must ensure that their tea crop is bountiful and pure enough to export to another country. With the recent earthquake and tsunami devastating parts of Japan and the fact that Japan is often subjected to earthquake tremors, new light has been thrown on the effects that such tremors may have on Japan's agriculture. Due to time constraints our experiment tests the common *Phaseolus vulgaris* as a substitute for *C. sinensis* making the assumption that agitation of *P. vulgaris* will have the same effect as it would on *C. sinensis*. A number of physical properties that signal a plant's health could be tested but we chose to focus on growth of shoots and visual health of plants because they are two measurements that can be easily standardized and understood. Our hypothesis was that the plants that were grown under constant agitation would have stunted growth compared to those grown under normal conditions. The assumption was made that the health of plants automatically correlates with the growth of a plant vertically. Another assumption that had to be made was that constant agitation of the test group would have the same effect as tremors from an earthquake.

Figures 4 & 5 (respectively): A side view of the shoots of a member of the experimental group and control group clearly shows differences in stem health and structure.

Materials & Methods

Ten, two week old plants were chosen based on their similarities in starting height. They were then standardized by cutting off all growth above the initial tertiary leaflet. Five plants were randomly selected for the control group and were placed in the Dunboff Metabolic Shaking Incubator and set at a moderate rate of agitation. The five control plants were raised to an equal height as the test plants in order to keep the light level at a constant $54.56\ mmol\ s^{-1}\ m^{-2}$. The water level was checked every day to make sure the water stayed at one cm above the base of the planters. Measurements were taken each week for five weeks.

Literature Cited

1. Anten, N. P. R., Casado-Garcia, R., and Nagashima, H. 2005. Effects of Mechanical Stress and Plant Density on Mechanical Characteristics, Growth, and Lifetime Reproduction of Tobacco Plants. The American Naturalist 166:650-660.
2. Bengough, A.G., Croser, C., and Pritchard, J. 1997. A biophysical analysis of root growth under mechanical stress. Plant and Soil 189: 155-164.
3. Jaffe, M. J. 1980. Morphogenetic Responses of Plants to Mechanical Stimuli or Stress. BioScience 30: 239-243.

Abstract

The earthquake that struck Japan's coast a month ago gained national attention for the damage caused by the tsunami that was caused by the earthquake. Japan's coast is subject to multiple earthquakes each year with tremors and aftershocks following. The quakes are bound to have an effect on the growth and development of *Camellia sinensis*, the tea plant, which is one of the most important exports of Japan. Due to the time restraints of this project, *C. sinensis* were not tested, instead two week old *Phaseolus vulgaris* were used to show the effects of constant agitation which might mimic the effects of the tremors of an earthquake. This study is meant to see what effects tremors may have on the growth and overall health of a plant. Our study found that the initial growth rate, based on height of a plant was noticeably stunted in the plants that were subjected to constant agitation. Our data also showed that the average percent growth of a plants total height during the five weeks of study was almost twice as great in the control plants than it was in the test plants.

Data/Results

Figure 1: Control Plant Growth

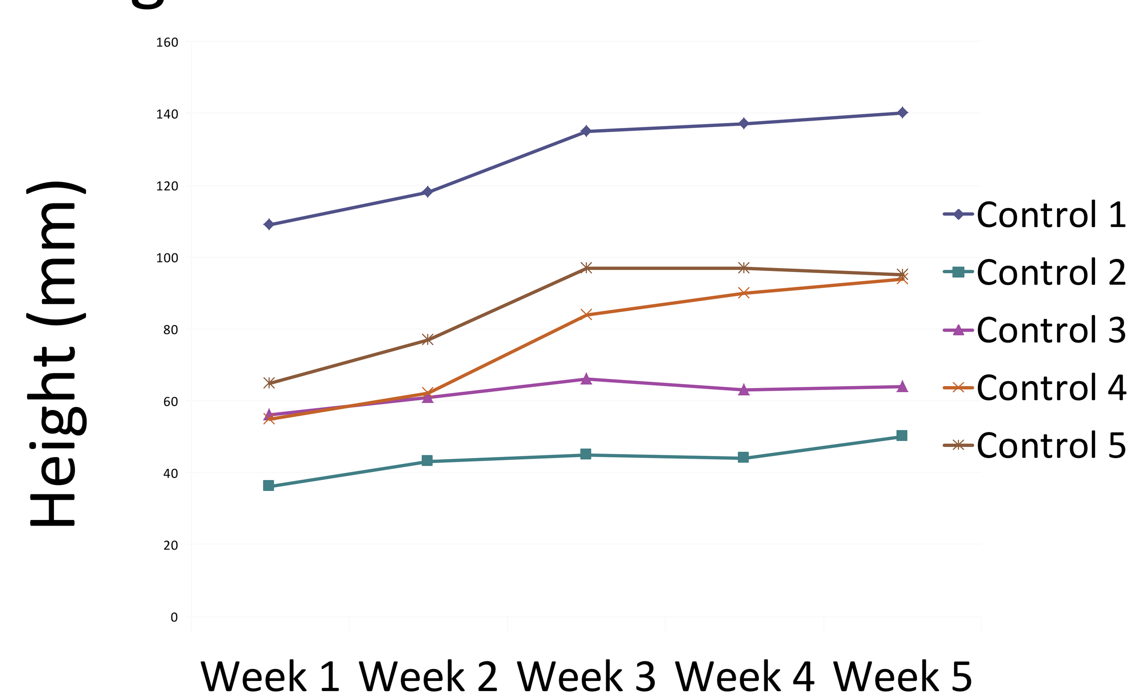
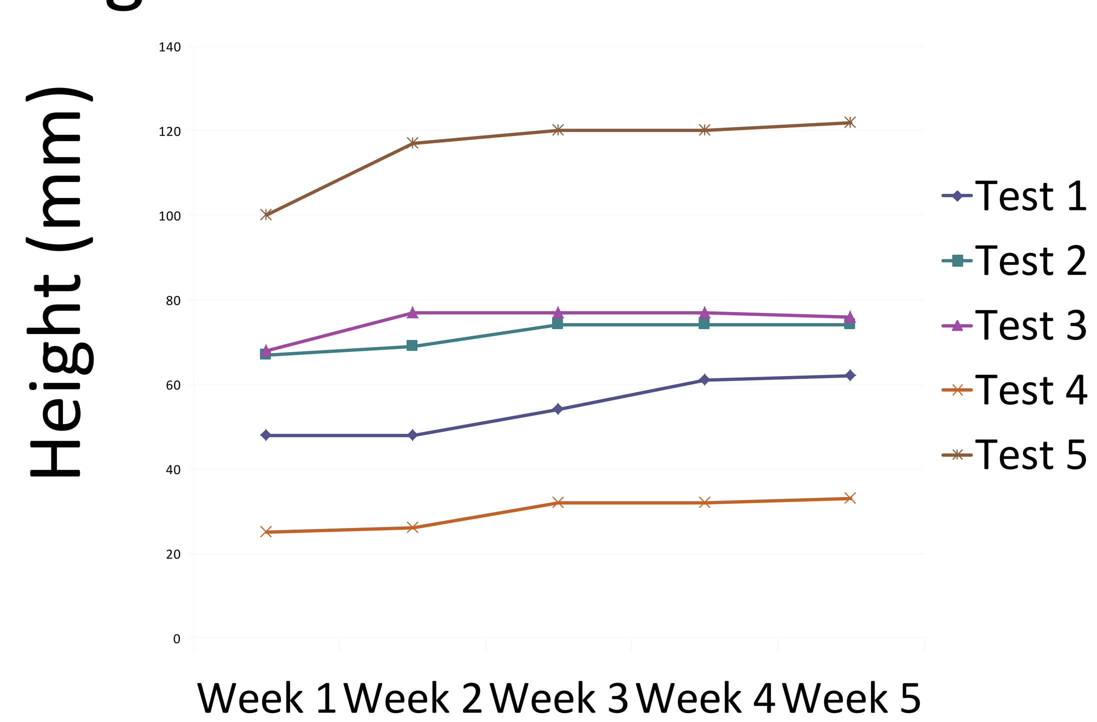


Figure 2: Test Plant Growth



	Average Initial Growth (Week 1 – Week 2)	Average Percent Total Growth During Testing Period (Week 1-Week 5)	Average Starting Height	Average Ending Height
Test Group	11.8 mm	17 %	61.6 mm	73.4 mm
Control Group	24.4 mm	27%	64.2 mm	88.6 mm

Table 1(above left): Differences in Growth of Test and Control Groups
Figure 3 (above right): Above view of the shoots of control and test individuals (top and bottom respectively)

The average total growth as a percent indicates that there is a ten percent difference in growth between the control and test groups within the five week testing period (which is later reflected in the final heights). When the initial average heights are considered, this appears to show an obvious favoring of shoot growth in control group individuals. This difference in shoot health is also reflected in the health of the leaves as per figure 3 (which was consistent among all individuals of the respective groups). However, when the data were analyzed using the student's T-test, the data proved to have no statistical significance ($T_{calc}=0.465 < T_{crit}=2.132$).

Discussion

As Figures 4 and 5 show, mechanical stress has a noticeable effect on the health of a plant, especially in the shoot morphology. During this procedure, it was intended that the base shoot diameter would be monitored over the duration of the experimental period. However, there were issues with proper measurement of diameter, and therefore the data were dropped from observation and omitted in this report. A potential solution to this lack of data would be to either conduct the same procedure with more mature *Phaseolus vulgaris* or to conduct the procedure with a species known for having a greater stem diameter. The same solution of using a different plant species applies for many of the other issues within the experimental design. Due to time constraints, root mass change was also not measured, but this will be recorded in future trials, due to its importance in stability (Niels P. R. Anten, Raquel Casado-Garcia, and Hisae Nagashima). With these limitations in mind, the main factor for determining whether plant stress has an effect on overall plant health was the height of shoot, as measured from the top of the soil to the shoot apical meristem (other notes in appearance were recorded as well).

Due to variations in initial shoot height, the measurements were converted into a form that shows the actual growth over the duration of the experiment: percentage growth as compared to the initial shoot height. Rather than having a greater distribution of varying raw values for growth, the percentage of initial height allows for a more standardized evaluation of the data. It is to be noted then, that the control group has an average percent growth of twenty-seven percent of the original shoot's height, whereas the experimental group had a seventeen percent growth of the original shoot height. Although these data might not have such a distinct difference, the distinction can still be made that the elongation of the shoot tends to be greater in the control group, which in turn suggests that physical agitation may play a role in the decreased shoot growth of a plant, although the current data cannot ascribe any statistical significance to it, based solely upon shoot height.

In future trials, root mass growth will be observed over time, as it is necessary for a plant to have an adequate root system in response to mechanical stress such as wind or earthquakes (N. P. R. Anten, et al.). A study by A.G. Bengough, C. Croser, and J. Pritchard suggests that mechanical stress that affects the density of soil can cause a shift in availability of minerals, water, and carbon dioxide. The constant shifting of soil over time could potentially contribute to resource availability in this manner. Depending upon the aim of further trials, this same portion of the procedure should remain intact.

Another consideration brought forth in Jaffe's paper on thigmomorphogenesis is that of the balance of plant hormones along a shoot. Tactile agitation of an internode of a bean plant shows a greater shoot diameter and decreased shoot elongation, which has been shown to be a responses to ethylene (Jaffe), which in turn is synthesized by auxin, which appears to be accumulated in the internodes in larger quantities upon tactile agitation. This same effect could be induced through simple agitation of the entire plant with consistency and would support the data and hypothesis in general. Further data collection and comparison of auxin/ethylene levels should be taken in future trials as a potential contributor to the mechanism by which this occurs.

Conclusions

- Although there is a visible difference in shoot structure and amount of leaf growth, the data does not suggest a statistically significant difference in shoot growth, although there is a difference. Therefore, the null hypothesis is accepted, but further research should be conducted.
- Past research suggests that the hypothesis is correct and suggests more attention be paid to hormone concentration and root mass growth as well as shoot height growth in future trials.
- The health of a *P. vulgaris* shoot is effected by agitation, but the extent to which and cause of has yet to be fully explored. Further trials should include *C. sinensis* but preliminary data are promising.

Acknowledgements

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