The Effect of Shaking on Mung Bean Growth

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Abstract
Much research has been conducted into the effects of mechanical stress on the growth of mature plants,[1] however little research has been done on its effects on seedling growth. Here we subject mung bean seedlings to horizontal oscillation using an orbital shaker. The plants were grown for 10 days under continuous oscillation at rates ranging from 0 to 200 revolutions per minute (rpm). The results show that the oscillation has a significant effect on stem growth, with increasing oscillation rate correlated with reduced growth. Increased oscillation also reduced central root growth and increased side root curling, but had no effect on leaf size.

Keywords: mung bean, growth, mechanical stress, circular shaking

I. INTRODUCTION

Looking at plants that grow along the beach where they are continually buffeted by the wind, it can be seen that they tend to have shorter stems than plants of the same species which are not exposed to the wind. It has been shown that plants grown in closed greenhouses tend to grow longer stems which are fragile and prone to breaking[1] due to the fact that they have not experienced any wind during their growth. We simulate the effect of wind stress by using an orbital shaker to study the effect of continual horizontal shaking on the growth of sprouting mung bean plants.

Researchers studying the effect of raising tomato plants in the dark and with no fixed gravitational direction, achieved by continual clinorotation, have found that these conditions resulted in strongly curved stems and curled roots. Raising them under clinorotation but with a fixed light source resulted in less strongly curved stems and curled roots. Planting mung beans under these conditions also produced curved stems, however the roots were only slightly curved.[2]

Several researchers have studied the effect of circular shaking on growing plants. Beyl and Mitchell found that shaking chrysanthemum plants for a short time each morning stunted their growth,[3] while Akers and Mitchell showed that shaking Alaska pea plants (*Pisum sativum* L.) for a short time every day reduced the yield.[4]

Here we subject mung beans to continual horizontal circular motion of varying frequency to determine the effect on stem length, leaf size, root length, and the inner cross-sectional structure of the stem.

II. METHODS

Preparation for Planting

A 1% w/v solution of Agar in water was prepared and boiled for 30 minutes. Thirty-two wide mouth, 300 ml jars were half-filled with the Agar solution and placed in a refrigerator overnight to solidify. The mung bean seeds were soaked in warm water for 10 minutes to decrease germination time[5] and 10 seeds were planted in each of the jars. The seeds were planted 1 cm deep in the Agar medium.

Growing conditions

The planted jars were divided into four groups of eight jars each. The first group was kept stationary as a control, and each of the remaining three groups was placed on an orbital shaker (figure 2). The three orbital shakers were set to oscillate at rates of 100, 150, and 200 rpms. The centrifugal force (RCF) experienced by each of the groups, shown in figure 1, was calculated as,

$$RCF = 1.12 \times Radius \times (rpm/1000)^2 \qquad (1)$$

Rate of Rotation (rpm)	Centrifugal Force (g-force)
0	0
100	1
150	2
200	4

Figure 1. Rate of rotation of each group and its approximate centrifugal force.

Plant Measurements

The growth of the bean plants was monitored for 8 days, starting 3 days after planting. Each day, one of the jars from each group was taken for measurement. Each of the plants in the jar was extracted from the growth medium and the following measurements taken: stem length (including both hypocotyl and epicotyl), leaf length and width, and root depth measured from the end of the hypocotyl. The shape of the root was also recorded and described qualitatively. On the last day, a freehand cross-section of the middle of the stem of 1-2 randomly selected plants from each condition was done and microscopic images recorded in order to observe the effect of the shaking on the internal cellular structure of the stems.

III. RESULTS AND DISCUSSION

Continual horizontal circular motion at different rotational rates for the first 10 days of growth has a clear effect on the growth of mung bean plants. Increased rate of oscillation results in significantly less growth, as seen in figure 3. It can also be seen that the size of the leaves does not seem to be significantly affected by the stress of shaking. It should be noted that the leaning of the plants observed in figure 3 is likely due to the fact that all the groups were grown in a room with sunlight entering from a single window to one side for the entire growing period.

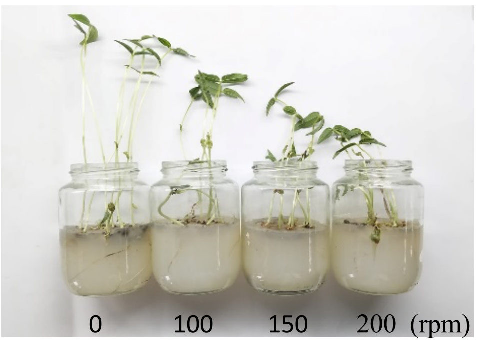


Figure 3. Growth of bean plants after 10 days.

Figure 2. The jars secured on the orbital shaker.

Looking at figure 4, it is clear that increasing the rate of oscillation results in a correlating decrease in stem height. After 10 days, the control group plants with no shaking had grown an average of 18 cm, but for each 50 rpm increase in oscillation rate the stem height decreased by about 2 cm. Upon conducting a paired sample t-test between the stem length of the control plants and the 200 rpm condition 10 days after planting, the results showed $t(2) = 40.6$, $p < 0.0$, meaning the stem length of plants under the 200 rpm condition ($M = 8.3$, $SD = 0.3$) showed a statistically significant reduction compared to the stem length of the plants under normal conditions ($M = 17.50$, $SD = 0.16$). This agrees with Mitchell's results showing that shaking produces stress in plants leading to reduced stem growth.[3] Our results also support Mitchell's results in showing that increased stress, caused by increased rates of oscillation, results in corresponding decreases in stem height.

Upon studying the characteristics of the stem cross-sectional images taken on day 10 (figure 5), it was found that plants grown under normal conditions

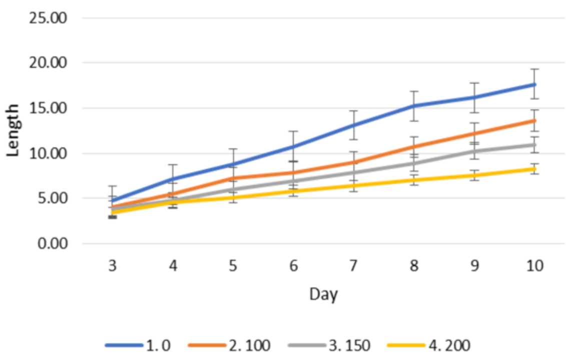
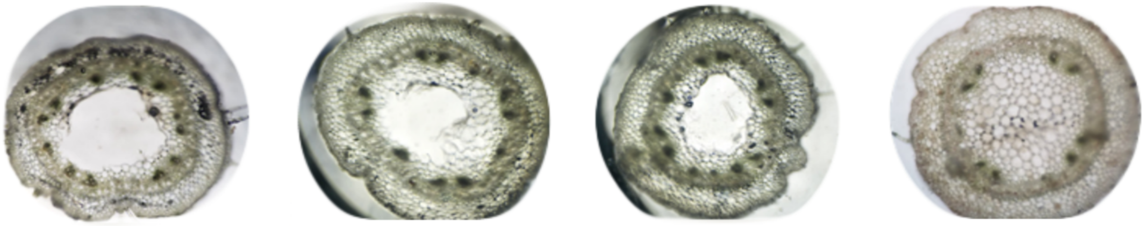


Figure 4. Stem length and oscillation rate over 10 days.



0 rpm 100 rpm 150 rpm 200 rpm

Figure 5. Images of the stem cross-sections of the plants grown under different conditions after 10 days growth.

had a larger area of empty space in the center of the stem, while plants grown under oscillation conditions showed reduced empty space. The stems of plants grown with no shaking had approximately 17% of the area with no cell structure, while the stems of plants grown under 100 rpm condition showed a reduced open area, about 15%. Those grown under 150 rpm conditions ended up with about 13% empty space and those grown at 200 rpm showed no empty space at all. The stress of shaking seems to have caused an increase in cellulose production in the cells in the stem. This might be the cause of the reduction in stem length, is it would mean reduced energy available for growth.

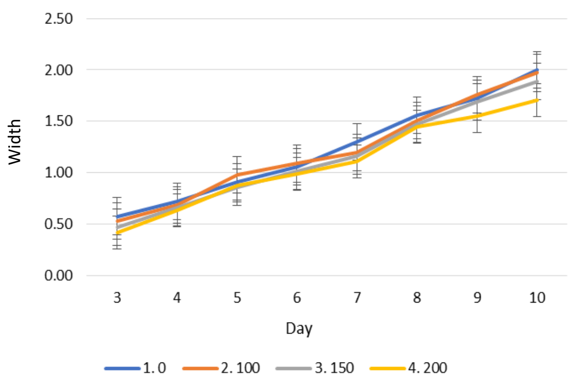


Figure 6. Leaf width and oscillation rate over 10 days.

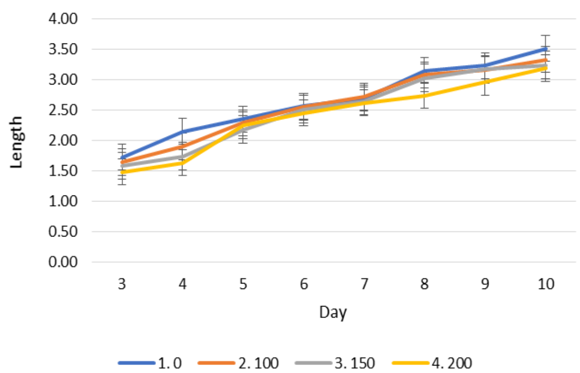


Figure 7. Leaf length and oscillation rate over 10 days.

From figures 6 and 7 we can see that increasing the rate of oscillation had no significant effect on leaf size for the first 10 days of growth. This is in contrast to Hammer's results which show that shaking reduces leaf size and quantity in grown plants.[7] It is possible that continuing to shake mung bean plants after they are fully mature might also result in reduced leaf size and number.

Looking at figure 8, it is clear that growing mung beans under oscillation conditions caused the side roots to curl, which was not found by previous research subjecting plants to horizontal shaking. Interestingly, this result was shown by Swandala when growing plants under clinorotation conditions.[2] The central root was shown to react similarly to the stem, with length being directly correlated to oscillation rate, as shown in figure 9.

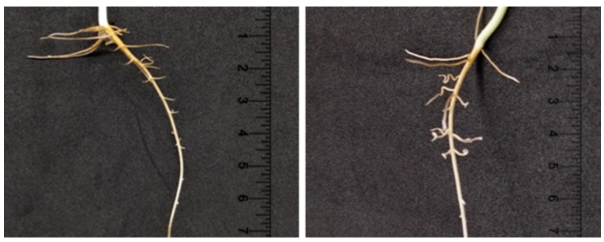


Figure 8. The roots of a plant grown under normal conditions (left) and at 200 rpm oscillation (right) after 10 days.

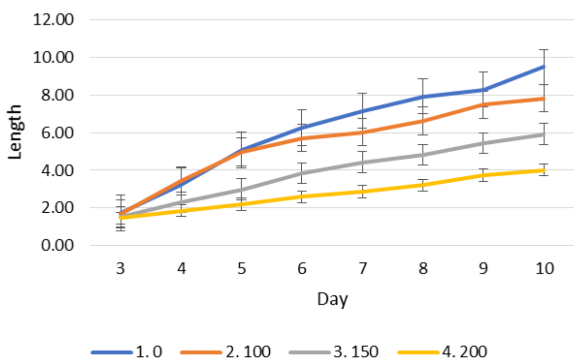


Figure 9. Central root length and oscillation rate over 10 days.

As we investigated the effects of oscillation on mung bean plant growth for only the first 10 days after germination, it is possible that plants will react differently as they mature. It is therefore recommended that further research be conducted on plant growth beyond 10 days. It would also be useful for research on the the effects of oscillation on other plant species to be conducted. Given that the lowest oscillation rate tested in this research was 100 rpm, further research into the effects of more gentle shaking on plant growth is also recommended.

IV. CONCLUSION

It was shown that growing mung beans under conditions of continual horizontal oscillation resulted in reduced stem growth and increased stem wall thickness, but had no effect on leaf size. Oscillation during growth also caused reduced central root growth and curling of the side roots.

V. REFERENCES

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