How Do Roots Grow When The Direction of Gravity Changes?
Abstract

From the moment a seed begins to germinate, the roots tend to go downwards, while the shoots grow upward. This normally occurs in nature, but we rarely pay attention to this wonder of the nature. Even in the past, scientists conducted various experiments to discover what makes the roots go downward and the shoots go upward. Now, we certainly know that gravity is what drives this incredible mechanism. Gravity sensing cells at the end of the roots called statocytes let the plant know the direction of gravity. This project was focused on understanding the mechanism of plants sensing the direction of gravity. We placed the seeds on a seed sandwich, which is created by placing a moistened paper towel on a CD case, and we altered the direction daily. After carefully obtaining the data, we analyzed it and found out that changing the direction that gravity acts on the seeds has a major impact on the way the roots grow. Knowing this amazing mechanism of the plants is vital for young scientists because in the future, a new area of sciences will open up when humans begin to live in space, where there is zero gravity.
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Introduction

Purpose

In the past, many scientists conducted various experiments to discover the extraordinary power that enable plants to move. Charles Darwin was among the first individuals to investigate the mystery. Darwin and many others certainly knew that gravity is what makes these plants change the direction, yet there were still many questions unanswered. A few months ago, I was reading an article written by Shawn Carlson in the Scientific American magazine, and at the same time, I heard about the science fair. The experiments that Carlson conducted inspired me to prove this notion for myself. As I thought about gravity and the way plants grow, I realized the importance of revealing the hidden mysteries of this area. Revealing these mysteries will allow scientists to grow plants in zero gravity if all other conditions are ideal. Most importantly, investigating this power of plants will open up a new area of science.

Experimental Question

How do roots grow when the direction of gravity changes?

Preliminary Research

Gravity is a dominant factor in the nature. It controls almost everything in the nature and can have effects that we could never have dreamed of. Although the amount of gravity exerted by different objects differs based on the mass, gravity is always the force that pulls down and keeps objects on the ground. However, gravity has many effects that we cannot see directly, but it does not mean that nothing is occurring. Geotropism is one of the major tropisms that directly impact the way a plant grows, and gravitational pull plays a major role in that situation.

Geotropism is a combination of the words ‘geotropic’ and ‘tropism.’ Tropism is the plant movement triggered by stimuli or environmental changes that affect the organisms.
Geotropism is a plant whose roots grow in response to gravity. Thus, geotropism focuses on gravity’s effect on the growth of plants’ roots. Anisotropic growth on the other hand, is the downward growth of roots and the upward growth of the stem. According to anisotropic growth, no matter which direction you turn a plant (i.e. sideways), the roots will continue to grow down and the stem will go in the opposite direction (up).

Geotropism is classified and logged into three different effects: positive, negative, and transversal (Figure 1). Positive geotropism measures the growth of the roots while negative geotropism is the growth of the stem. Negative geotropism is the growth of the roots (growth of the roots downward). Transversal geotropism is the direction of growth vertical to the plants stem.

Geotropism is crucial for the growth and survival of a plant. As a seed, they cannot feel the sunlight and thus cannot physically see where to grow up. By sensing the gravity, plants can turn sideways, upside down, etc. Scientists first theorized that the plant could tell by the warmth of the plant soil but now we know that they sense gravity and automatically know where down is and grow upwards. This is a crucial skill for plant because they need to grow upwards and get their leaves out of the soil so they can reach the sunlight and grow. Even though it seems easy to understand that plants sense gravity, the actual mechanisms inside the plant roots are quite complicated. Statocytes are a kind of cell that surrounds the rootlet tips. Inside those Statocytes, the statoliths act as a motion sensor. Movements of these small bodies allow the roots to understand the direction of gravity.

Plants, fungi, and microorganisms respond to stimuli that act with greater force from one direction than another direction by turning themselves with respect to the direction that the
stimulus is acting. Auxine is a special plant hormone that makes the plant bend in response to gravity. There is nearly three times as much auxine in the roots compared to the stem.

Auxine works as a sensor. Its imbalance due to gravity signals the plant to grow in response. In plants that grow with ideal positive and negative geotropism conditions, the auxins will be evenly distributed (Figure 2). If any changes occur in the position of the plant, then the auxins will always gather at the bottom, which will let plant know which way is “down.”

Although it is incredibly rare, some plants (often fungi) posses the ability called auto tropism. Auto tropism is the plant’s ability to compensate for a change in gravity. For example, if we were to plant a mushroom sideways, sooner or later the mushroom would bend its stem until transversal growth occurred (The stem grew upwards while the roots grew downwards).

**Hypothesis**

If we alter the direction of gravity, then the plants will continue to grow toward the direction of gravity.
Experiment

Materials

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<tr>
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<tbody>
<tr>
<td>Seeds</td>
<td>1 package (Radish seeds are ideal because they germinate rapidly.)</td>
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<tr>
<td>Paper Towel or Blotting Paper</td>
<td>At least 4 (Require more for trials)</td>
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<tr>
<td>CD cases or Plastic Bags</td>
<td>At least 4 (Require more for trials)</td>
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<td>Squirt Bottle of Water</td>
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<tr>
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Procedure

To begin the experiment, first start with soaking the paper towel with water. Since the seeds are tested for 4 different directions, there must be at least four paper towels. Allowing them to absorb a certain amount of water is very important because it makes sure that the plants survive instead of wilting. Next, obtain four CD cases and insert the wet paper towels into each case. After that, choose some healthy looking seeds and carefully place them on the wet paper towels. Rapidly germinating seeds, such as Radish seeds (*Raphanus sativus*), are ideal for this experiment because they help to obtain quick results. After placing the seeds, carefully close the cover. Make sure that the seeds do not move while inside the CD casing. Next, use a marker to give each CD casing a number and the direction that they are going face (Up, Down, Left or Right). Then use modeling clay to hold your seed sandwich. Let the seeds germinate and the rootlets start to grow. Keep the seeds moistened by carefully inserting drops of water on a daily basis. On each day, change the direction of the seed sandwich to observe the way they grow under certain circumstances. While observing the way they grow, record the data for further references.
By constantly altering the direction of the seed sandwiches, we obtained data all through the days of experimentation. As it can be seen in the data tables, different seeds had different growth rates. Most of them grew rapidly, but some of them showed a slow growth. By changing the direction of the seed sandwiches, or the direction that gravity acts on the plant roots, it was possible to observe certain increases and decreases in the root growth. As the direction of seed sandwich changed, the roots began to bend and grow vertically. Since the direction of the seed sandwich continued to be changed day-by-day, at the end of the experiment the roots could be observed, and they appeared to be in the pattern of mazes. Even though the directions of the seed sandwiches were altered, some of the seeds continued to grow at the same rate.

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Figure 3: Pictures obtained throughout the experimentation
Analysis

Data Analysis

According to the data obtained through all the days of experiment, it is apparent that gravity is an important stimulus that impacts the growth of roots. Since the goal was to determine how gravity affects the growth of roots, the direction of gravity was constantly altered. Since the direction of the roots was constantly altered, the roots sensed this change and they began to respond to this change of stimulus by changing the way roots grow. It is certain that the only stimulus that triggered this change was gravity because the direction of gravity was the only factor that was changed throughout the experiment. In the experiment, it can be clearly seen that there are some differences in the growth rate of the seeds. Since that question cannot be answered through the experiment that was conducted, another experiment might need to be conducted in order to reach a conclusion as to why they grew at different rates. However, by observing the data collected it can be decided that positive and negative geotropisms (shoots: negative geotropism, roots: positive geotropism) are totally controlled by the direction in which gravity acts upon the plant.

Scientific Discussion

Geotropism is the growth of an organism in response to the gravity. Plants are mainly affected by the gravity because shoots travels upward (negative geotropism) while the roots travel downward (positive geotropism). For the ease of study, most scientists divided this complex process into three main sections: perception, transduction, and response. Perception is the process of understanding the stimuli from the surrounding that helps the organisms to survive and reproduce. In plants, gravity is sensed by are group of cells called statocytes (Figure 4). Statoliths are small bodies that are placed inside the statoliths, and they play a major role in plants sensing
the direction of the gravity. In order to understand how the statoliths work, think about placing a small rock inside an inflated balloon. When the balloon is moved, the location of the rock is audible and can be visualized. In the same manner, plants sense the direction of gravity when these special statoliths touch the bottom of the cells.

Knowing the direction of gravity is not enough for the survival of a plant. They should be able to communicate with other areas of the roots so they can grow according to the information that is provided by the statoliths. Before sending the message to other areas, it is crucial to convert the signals provided by the statoliths into chemical signals so that they are understandable. The process of converting physical information into chemical signals that the plants can understand is called transduction. Transduction is one of the most important concepts in biology, and in fact humans survive because of the transduction that their bodies conduct. For example, humans are capable of hearing sounds because a special mechanism in the inner ear allows changing sound impulses into electrical signals that the brain can easily understand. When signal transduction occurred in root cells, the plant is ready to act upon the received information. When root tip cells receive all these chemical signals, the plant responds by growing the root in the direction of gravity.

**Error Analysis**

Even though the attempt was made to complete this experiment without any errors, still there is chance of making at least a single error. Since the roots worked with were so sensitive to stimuli, minor movements of the seeds might have caused an error. For example, when the CD cases were opened to water the plants, it was possible for an error to occur if the position of the
seeds was changed. Other than those errors, the effects of the environment such as the air temperature and lighting at the time of the day might have an impact on the growth of seeds. Since it was desired to obtain legitimate data, the attempt should be made to minimize the number of careless mistakes made throughout the experiment.
Conclusion

This experiment was conducted to investigate about how the alternations of gravity impact the growth of plant roots. A series of experiments were conducted by changing the direction in which the gravity impacts the plant. On each day, the seed sandwiches were turned clockwise. At the end of the experiment, the data were thoroughly analyzed and the answers to the question were able to be determined. As it was hypothesized, changes in the direction of gravity had clear impacts on the way plant roots grew. No matter how many times the direction was changed, plants always showed the positive and negative geotropisms (Roots go downward and stem goes upward). Changes in gravity had certain impacts on the growth rate of plants too; however, in order to clearly understand how gravity affects the growth rate, different experiments need to be conducted. The experiment was totally successful, and at the end of the experiment hypothesis it was proved that our hypothesis is true and supported by valid data.
Acknowledgments

Apart from our dedication to this project, the success of this project totally depends on encouragements and guidance of many other individuals. Unless for the tremendous support that they provided us from the beginning, this project would have been quite difficult because of its complexity. Most importantly, at this moment we are grateful for the cooperation that existed between us. Unless for the strong mutual aid, this project would have taken a long time to materialize because of the confusing areas that we consistently confronted. Furthermore, we would like to thanks to our parents for providing us all the necessary materials. Also, we are grateful for the freedom that they provided for us to work together to successfully complete this project. Furthermore, we are grateful for the constant guidance that our biology instructor, Mr. Espinoza, provided us throughout the months of this project. He kept us alert about the project all the time, which we believe as a huge support for the success of this project. Again, I am grateful for the constant support that everyone provided us to complete this science fair project, and certainly we were able to finish this project better than we thought we would do.
References


