A Closer Look at Root Tropism

Stiftsschule Einsiedeln SFBC 4

Introduction

Roots are arguably the most important part of a plant, as they are the lifeline of the plant, making sure that it has enough nutrients, air and water from the soil to live on. These are then moved up the root system and stem and transported to the leaves. There, the plant uses the water and combines it with sunlight to conduct photosynthesis and thereby produce energy.
Not only do roots make sure the plant doesn't die, but they also keep it in place, together with the soil. Roots are a key factor to preventing soil erosion (Net Industries). The root system furthermore stimulates the growth of micro- and macro-organisms in the soil and by that help to maintain its fertility. On top of that scientists have made the discovery that roots alter soil chemistry by secretion *(Bonnie Plants).*
Plants and especially the roots also play an important part when it comes to guttation. Not to be confused with transpiration, which is the loss of water of a plant through water vapour, guttation is the loss of water of a plant by water drops, usually visible on the leaves of a plant. If the soil is exposed to massive amounts of water, the root system will absorb this excess water by active uptake, developing hydrostatic pressure in the process. This pressure pushes the water upwards into the water stomata (hydathode) *(Major Differences, 2014)*, where the pressure further builds up with more and more water being pushed up. The pressure is finally released when the water is eventually pushed out of the pores *(Fagerstedt, 2004).*
As for economic value, one could say that roots play a highly important part in agriculture. They are rich in carbohydrates and are therefor essential when it comes to battling worldwide hunger.
Roots are usually found underground, however, they can also be aerial, meaning above the ground. Internally, a root consist of a vascular system surrounded by the pericycle, the cortex tissue, and the epidermis, which is the outermost layer of tissue. The vascular system, consisting of xylem and phloem tissue, is responsible for transporting nutrients, water and educts of photosynthesis. The two main types of roots are taproots and fibrous roots. Taproots consist of a primary and secondary roots and are known to be more resistant, whereas the fibrous root system has many equally sized roots emerging from the seed.
Roots generally have four main functions, which are 1) a stabilizing and supporting agent for the plant in the soil, 2) a way for the plant to store important nutrients for growth and survival, 3) important for the plant to reproduce asexually and 4) used by the plant to adsorb water and minerals.
We have decided to focus our attention on the most fascinating aspect of plants - root tropism. Plants depend on sunlight for photosynthesis and therefor growth, but when it comes to roots, things are different. In the soil, there is no sunlight to guide them. What we wanted to find out in our experiments is what factor affects root tropism the most? Light, gravity or type of soil?

How is root tropism affected by light?

For this experiment two dark boxes with small holes of approximately 2 cm x 4 cm were used to allow light to enter the box from only one direction. Each of the Boxes was provided with a 6 cm petri dish and a 10 cm petri dish. The 10 cm dishes agar was flipped upside down on to a metal grid, to allow root growth in any possible direction. Dishes in box A were provided with four monocotyledon seeds (cat grass, *Cyperus zumula*) in the small petri dish and four dicotyledonous seeds (*mung bean, Vigna radiate)* in the big petri dish. Dishes in box B were provided with four dicotyledonous seeds (*mung bean, Vigna radiate)* in the small petri dish and four monocotyledon seeds (cat grass, *Cyperus zumula*) in the big one. In both cases the light source was placed in front of the opening of the dark chambers.

Figure 1: Set up Experiment 1

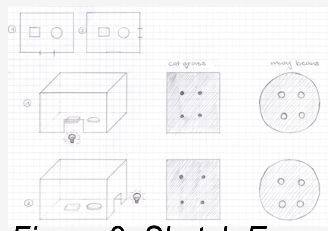


Figure 2: Sketch Experiment 1

How is root tropism affected by gravity?

Five 6 cm petri dishes were seeded with a total of four dicotyledonous seeds (*V. radiate*) and an additional five petri dishes were provided with four monocotyledon seeds (*C. zumula*) each. The dishes were labeled with M for 'mung beans' (*V. radiate*) and K for 'cat grass' (*C. zumula*). The seeds were pushed carefully in to the agar to prevent them from dropping out during the experiment.
The experiment was set up by adjusting the petri dishes at five different angles using stands and clamps at 0°, 45°, 90°, 135° and 180°, using one of the two seed types for each angel.

Figure 3: Set up Experiment 2

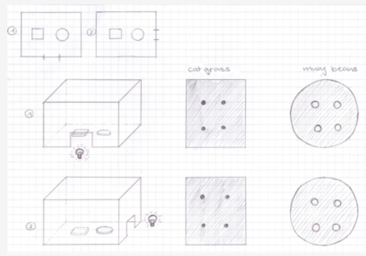


Figure 4: Sketch Experiment 2

How is root tropism affected by substrate?

A line was drawn on the bottom of six 10 cm agar dishes to separate the petri dishes in two. Three petri dishes were seeded with a total of two dicotyledonous seeds (*V. radiate)* per dish and an additional three with two monocotyledon seeds (*C. zumula*) per dish. The positions of the seeds were also indicated on the bottom of the plates. Furthermore, half of the agar was removed according to the previously drawn line using a scalpel. The empty space was filled with dampened cotton. There were now two different media, one possibly more fertile than the other. The seeds were placed in three different ways: on the agar, on the cotton and on the middle.

Figure 5: Set up Experiment 3

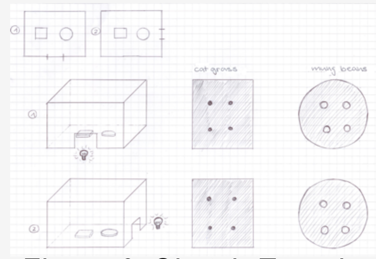


Figure 6: Sketch Experiment 3

Figure 7: Clas involvement

Variables

Controlled variables
Seeds were placed on 1,2% Agar Gel in petri dishes of various sizes. To ensure sterility of the agar it was exposed to UV-light before being used in the experiment.

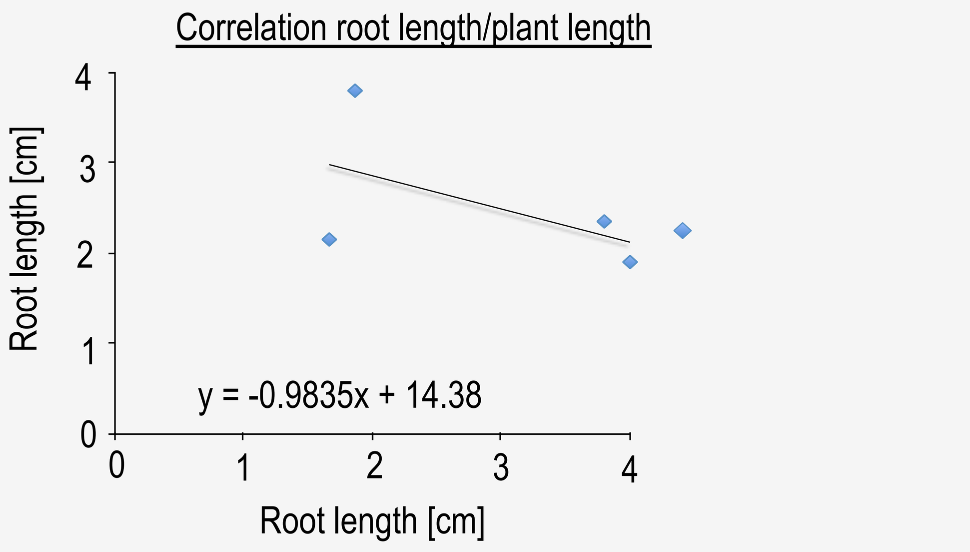
- The experiment lasted 7 days
- No light (if not explicitly stated in the description)
- Temperature 21°C and Humidity of ~100% (closed humid dishes).

Independent variables
Are indicated in the methods part.

Dependent variables
After a week, the experiment was terminated and the roots were measured, using thread and ruler, weighed using a highly sensitive scale and the direction of the root tropism according to the varying variable was measured.

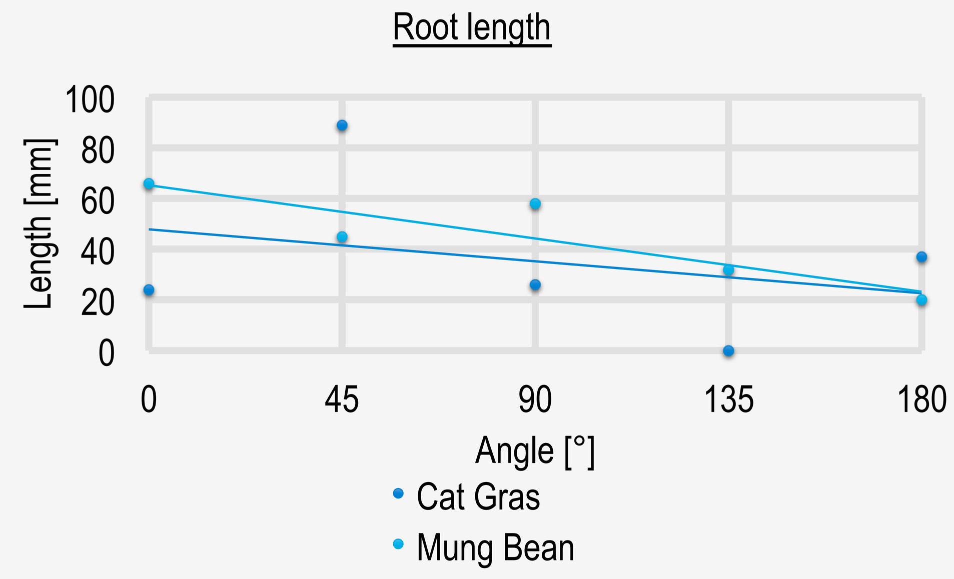
Figure 8: Mung bean

Results Experiment Light



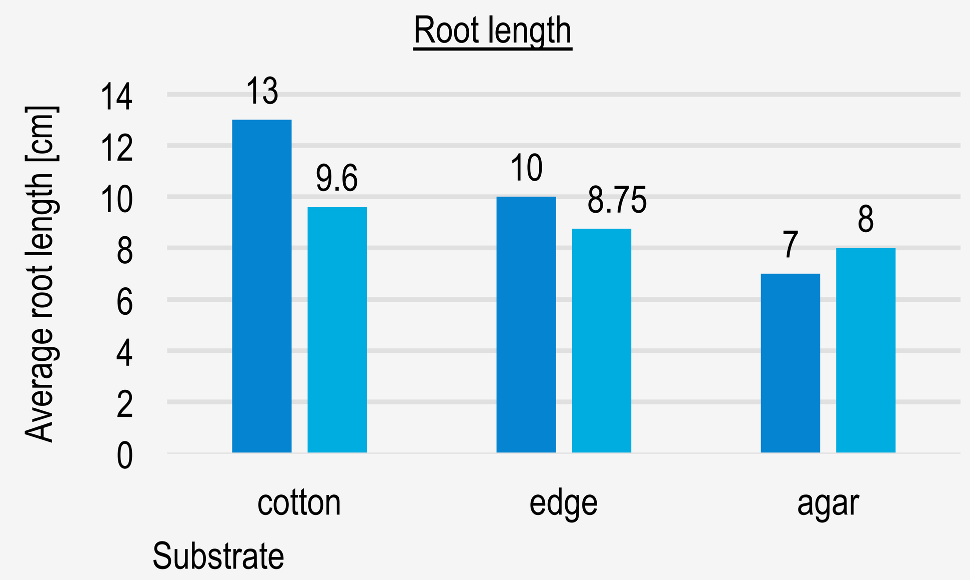
This graph shows the correlation between the length of the root and the length of the plant. It shows that the bigger the shoot, the smaller the root and vice versa.

Results Experiment Gravity



The graph shows the length of the roots comparing the two different seeds. It is clearly visible that the cat grass seeds were smaller in length, although the both had the same length at 180°.

Results Experiment Substrate



The dark blue bar describes the cat grass, the light blue bar the mung beans. As you can clearly see, the roots of the mung beans are usually longer than the cat grass ones and the roots of the seeds in the cotton are the longest, whereas the roots of the seeds in the agar are comparatively short.

Discussion

The data of the dependent variables was collected and analysed at the end of the experiment.
In the experiment considering root tropism in respect of an artificial light source we found the artificial light not to have an impact on the roots, they still grew downwards towards the floor although the shoot seemed to grow towards the light. Also, there is a negative correlation between the growth of the plant and the growth of the roots. The mung seeds (*Vigna radiate*) in the experiment and negative control had the same weigh, however the grass seeds (*Cyperus zumula)* used in the experiment were slightly less heavy (0,025 to 0,03g) than the ones from the negative control. On average, the roots in the experiment were smaller. This might have been caused by the absence of light and therefor less energy available for the roots to grow. Furthermore the experiment lasted only for 7 days, during which energy production by means of photosynthesis seemed not to have any beneficial effect on root growth.
In the experiment considering root tropism in respect of gravity we found that even when altering the orientation of the petri dishes (0°, 45°, 90°, 135°, 180°), the gravitational force had a bigger impact on the growth direction of the roots than the orientation of the dish. They all grew straight down towards the ground. We therefore suppose that there must be some parts of both the monocotyledon and the dicotyledon roots that help them detect gravity, to grow accordingly. Furthermore, the plant couldn't conduct photosynthesis as it grew without light. Having not formed chlorophyll because of that reason, the plants remained white instead of turning green. This process is called etoliation (Wikipedia, 2006) and happens when a plant grows in the absence of light. There are differences in length and weight between the roots, which can be explain by how how much effort the plant had to put into growing downwards. The more way the plant had to go, the more it weighed. The cat grass (*C. zumula*) in the 135° hadn't sprouted at the point of data collection, so no development could be observed nor could any data be obtained.
In the experiment considering root tropism in respect of the substrate we could not gather enough information to see if root tropism is influenced by the substrate. Interestingly, the mung bean (*V. radiate*) roots in this experiment were the only ones that had been forced out of the substrate, which can be explained by the better water absorption in the agar-agar. When measuring the length of the grass (C. zumula) roots, we found that the ones in the cotton part were the longest, followed by the ones in the middle, whereas the ones in the agar-agar were the shortest. This observed trend is not valuable though as we only had one seed for each substrate. All of the roots grew towards the floor as far as possible but they were restricted by the petri disk.
Generally, the experiments were successful and interesting, the teamwork well done and the data gathered useful. Mostly through careless handling, like destroying the cap of a petri disk while trying to install it or opening the petri disks after they had been exposed to UV-light, mistakes could have been prevented. Also, we had to leave the petri disks closed, so the mung bean (*V. radiate)* could not develop properly. If we were to repeat the experiment, we could maybe conduct it in a more/less humid environment or use bigger petri disks. Also, we should have labeled our petri disks more carefully.
One major problem present in all of the experiments was the germination rate of the monocotyledon seeds of *C. zumula*. With not all seeds germinating properly, data collection could not always be conducted as planned. For follow-up experiments we therefore strongly recommend to increase the number of seeds per experimental assay, as this would have enabled us to draw statistically more relevant data from all of our experiments see the trends in our findings more clearly. We didn't have that much time on our hands, otherwise we would have repeated our experiment in order to receive more relevant data.

References:
1 Net Industires, Roots System- Importance of Roots, http://science.jrank.org, http://science.jrank.org/pages/5923/Root-System-Importance-roots.html, 11.05.2015
2 Bonnie Plants, The Importance of Roots, http://bonnieplants.com, http://bonnieplants.com/library/the-importance-of-roots/, 10.05.2015
3 Major Differences, Difference between Transpiration and Guttation, http://www.majordifferences.com ;http://www.majordifferences.com/2013/02/difference-between-transpiration-and.html#.VVNE3ikxH-Z, 2014, 11.05.2015
4 Fagerstedt, Kurt, Water Relations in Plants, Helsinki University, Finland, Eolss, Paris, 2004
5 Wikipedia, http://en.wikipedia.org/wiki, Etiolation, http://en.wikipedia.org/wiki/Etiolation, 12. September 2006, 13.05.2015