Effect of gravity and centrifugal force on plants

Students learn how the change in gravity caused by a centrifuge affects root and shoot growth.

Biology | Plant Physiology / Botany | Germination, growth, development

Difficulty level	Group size	Preparation time	Execution time
easy	2	20 minutes	45+ minutes

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE excellence in science

General information

Application

PHYWE excellence in science

Experiment setup

In this experiment it is observed to what extent the plant reacts to gravity with which parts of the plant.

Special attention is paid to how the plant behaves when gravity is changed by a centrifuge. For this purpose, the growth directions of shoot and root are considered.

PHYWE excellence in science

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (1/3)

PHYWE excellence in science

Prior knowledge

Students should be aware that in a moving centrifuge the gravity vector approaches the horizontal with increasing speed.

Scientific Principle

The main shoot of a plant follows the vertical against gravity (negative geotropism), whereas the main root grows in the direction of gravity (positive geotropism).

Other information (2/3)

PHYWE excellence in science

Learning objective

Students learn how a change in gravity through a centrifuge affects root and shoot growth.

Tasks

The students measure the orientation of shoots and roots under the influence of centrifugal forces, which are lower, equal or greater than the gravitational force. To do this, they make sunflower seedlings grow in a rotating drum. This experiment is carried out with different centrifugal forces by changing the rotational speed of the drum motor.

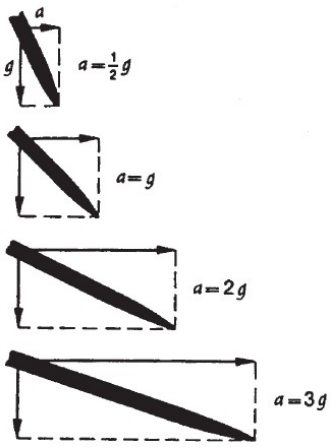
PHYWE excellence in science

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (3/3)



Root direction

Observations and results

The predicted orientation of the shoot and root is calculated for each of the four speeds studied by means of a parallelogram of forces based on gravity and centrifugal force (Fig. left). The measured shoot and root orientation (the average of 8 angular measurements per U / min for each) proves to be in good agreement with the calculated value. As can be seen from the figure, with increasing centrifugal acceleration, the embryo plants become increasingly tilted towards the rotating disc, with the shoot towards the centre and the root away from the centre.

Safety instructions

- The general instructions for safe experimentation in science lessons to be applied to this experiment.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Theory

The main shoot of a plant follows the vertical against gravity (negative geotropism), whereas the main root grows in the direction of gravity (positive geotropism).

When the plant is held in the rotating horizontal position, this changes the direction of growth of the shoot and root.

Gravity and the centrifugal force created by rotation are obviously perceived as identical by the plant. Both forces exert a compressive force on the starch grains present in the cytoplasm. These grains probably act as statoliths (just as in animals) for detecting the stimulus of gravity. Only these still growing zones of the shoot and root can respond to this stimulus, since geotropic behavior is based on growth movements.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Strobe drum	65976-00	1
2	Insertion piece for centrifuge	65976-10	1
3	Motor with disk holder	11614-00	1
4	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
5	Connecting cord, 32 A, 750 mm, red	07362-01	1
6	Connecting cord, 32 A, 750 mm, blue	07362-04	1
7	Support base, variable	02001-00	1
8	Boss head	02043-00	1
9	Support rod, stainless steel, 500 mm	02032-00	2
10	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
11	Beaker, Borosilicate, tall form, 50 ml	46025-00	10

PHYWE excellence in science
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE excellence in science

Structure and implementation

Set-up

PHYWE excellence in science

- The strip drum is fixed in a hole of the stand base and the 500 mm long stand rods are inserted into the base from the side (Fig. Experimental setup on slide 2).
- The 250 mm long stand rod is fixed with the other hole of the stand foot. The motor is clamped to this stand rod by means of a right-angled clamp so that the motor pulley is at the same height as the bottom of the drum.
- The drive belt is then attached and tightened. In order to keep the distance between the motor and the drum constant, the stand rods, which have been inserted on the side of the stand base, are securely fastened with the yellow levers.
- The motor is connected to the current output of the power supply unit via the two connection cables. The voltage is first set to OV / 2A and switched on.

PHYWE excellence in science
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Procedure (1/2)

PHYWE excellence in science

- A sunflower seed or seedling is planted in each of 8 beakers and filled to the rim with planting soil. The beakers are inserted into the holes of the centrifugal insert so that the rim points exactly to the centre of the disc. After removing the stand rod that protrudes from the drum, the centrifugal insert is placed in the drum along with the beakers. It is important to ensure that the centrifugal insert is positioned exactly in the horizontal plane.
- The power supply voltage is set so that the drum rotates at about 60 rpm. The centrifugal acceleration a at this speed of rotation is equal to half the acceleration due to gravity g. The simplest method of determining the speed of rotation is to attach a piece of string to a point on the rim of the drum so that it comes into contact with the experimenter's hand at each rotation of the drum.
- The sunflower seeds or seedlings are exposed to acceleration in the centrifuge for a few days. Since the soil dries out quickly during centrifugation, the beakers must be thoroughly watered at least once a day.

Procedure (2/2)

PHYWE excellence in science

- When the sprouts have reached a length of about 3 cm, the experiment is stopped and the beakers are removed from the centrifugal insert. The inclination of the shoot in each beaker is immediately measured and recorded using a goniometer (angle measuring device). The position of the tip of the root is also determined and used to determine the direction of growth of the roots.
- The experiment is repeated at a drum speed of 85 rpm (= 1 g), 120 rpm (= 2 g) and 150 rpm (= 3 g) each time using fresh seeds or seedlings.

Experiment setup

PHYWE excellence in science

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

PHYWE excellence in science

Report

Task 1

PHYWE excellence in science

What is meant by negative geotropism in the context of this experiment?

- ○ That the main shoot of a plant follows the vertical against gravity.
- ○ That the plant grows upside down.
- ○ That the main root of a plant follows the vertical in the direction of gravity.
- ○ None of the answers are correct because there is no negative geotropism.

Check

PHYWE excellence in science
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Task 2

PHYWE excellence in science

What is meant by positive geotropism in the context of this experiment?

- ○ This means that the main root grows in the opposite direction of gravity.
- ○ This means that the plant can only grow in positively charged rock, since it has been polarized by the centrifuge.
- ○ This means that the main root grows in the direction of gravity.
- ○ None of the answers are correct because there is no positive geotropism.

Check

Task 3

PHYWE excellence in science

Based on this experiment, what do gravity and centrifugal force obviously exert?

- ○ Gravity exerts a pulling force that pulls the starch granules downward in the plasma, while centrifugal force creates a pushing force that pulls the starch granules upward. This is why the starch grains are usually oval shaped.
- ○ Both forces exert a pulling force on the starch granules present in the cytoplasm.
- ○ Both forces exert a compressive force on the starch granules present in the cytoplasm.

Check

PHYWE excellence in science

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Slide	Score/Total
Slide 14: Negative geotropism	0/1
Slide 15: Positive geotropism	0/1
Slide 16: Gravity and centrifugal force	0/1

Total 0/3

Solutions Repeat

PHYWE excellence in science
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de