# THE SCIENTIFIC JOURNAL

# WELCOME TO YOUR VERY OWN SCIENTIFIC JOURNAL.

## LET THE FUN BEGIN!

# INTRODUCTION

Even though plants are **a fundamental pillar of life on Earth**, their essential significance is frequently overlooked.

Not only do **plants** provide oxygen, food and shelter for many animal species, but they also **play a critical role in maintaining the biodiversity and stability of the world's ecosystem**. However, many people continue to perceive plants only marginally.

This phenomenon even has a name and is defined as so-called "Plant Blindness". This phrase is used to refer to the tendency to overlook plants and mainly focus on fauna. Perhaps, this is also because plants move so slowly that they seem to us to be motionless and as such they do not demonstrate the pronounced behaviour of animals. **Their presence is often perceived as a matter of course**, as static greenery constituting a backstage for the dynamic world of animals and people or as a setting for other events that seem more interesting at first glance. Their hidden, but often very rich lives thus remain unknown to many.

**In order to assist in extending our understanding of plants, we have designed a series of plant experiments in the AlbiLAB in cooperation with the researchers from the Institute of Botany of the Czech Academy of Sciences.**

We are sure that these experiments and the others that you come up with yourself will provide a unique **opportunity to investigate the fascinating world of plants** and their interaction with the environment they live in.

**The AlbiLAB comprises two main components: the electronics and the growing area. The electronics control the operation of the various devices, sensors and lighting**, while the growing area provides the environment for growing plants such as the Thale Cress, whose seeds come with the AlbiLAB kit.

The choice of Thale Cress as the main model species for the experiments in the AlbiLAB was not a random one. Thale Cress is highly valued in in plant science for its fast growth and easy genetic manipulability. These properties have led to it becoming a model for studying plants and it has provided scientists with valuable information about how plants respond to their environment and how they function at a molecular level. Studies of Thale Cress have helped reveal a number of fundamental principles of plant biology, including the mechanisms that plants use to react to light, temperature and other natural factors.

The AlbiLAB kit enables users to cultivate Thale Cress and to experiment with it in an environment that simulates various ecological conditions.

The kit's electronics enable the regulation of the light and humidity conditions (add-on modules), which provides users with control over the environment the plants are growing in. As such, users can **monitor how the plants respond to different conditions and thus acquire a deeper understanding of plant biology and ecology**.

We have prepared several experiments for you that will reveal **how plants respond to different natural conditions**.

**In addition to patience and precision, the basis of every scientific experiment is a well-controlled environment that enables the exclusion of any unknown factors that could influence the experiment results.** AlbiLAB enables the user to control the length of the day (light), its intensity and its spectral composition (the ratio of white, blue and red light).

The basic kit controls the light conditions for both growth chambers jointly, while the expansion module enables the light conditions to be controlled independently for each growth chamber. Therefore, **the proposed experiments anticipate the same light conditions in both growth chambers.** Nevertheless, this still enables the user to do some interesting experiments before expanding the kit to start simulating different light and other conditions in the separate growth chambers.

Before starting any tests, it is a good idea become more closely acquainted with the main hero of your experiments. Thale Cress, in Latin *Arabidopsis thaliana*, is a small plant from the Brassicaceae family and is therefore related to many well-known types of vegetables including cabbage, kohlrabi and broccoli.

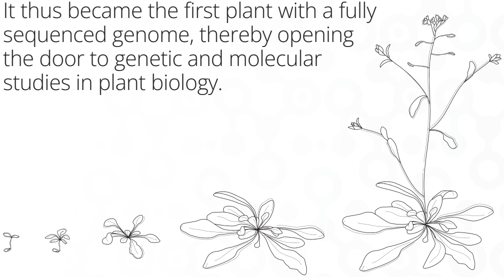
## THALE CRESS



Thale Cress is well known for its ability to complete its life cycle within just six weeks. In other words, it takes just six weeks from sowing the seeds **to the production of mature seeds under ideal conditions.** Thale Cress blooms with small white flowers and forms its seeds in small siliques.

The thing that makes Thale Cress so attractive for scientific research is its **simple genetic structure** and the aforementioned **fast generative cycle**. It has a relatively small genome which was fully sequenced in 2000.

It thus became the first plant with a fully sequenced genome, thereby opening the door to genetic and molecular studies in plant biology.



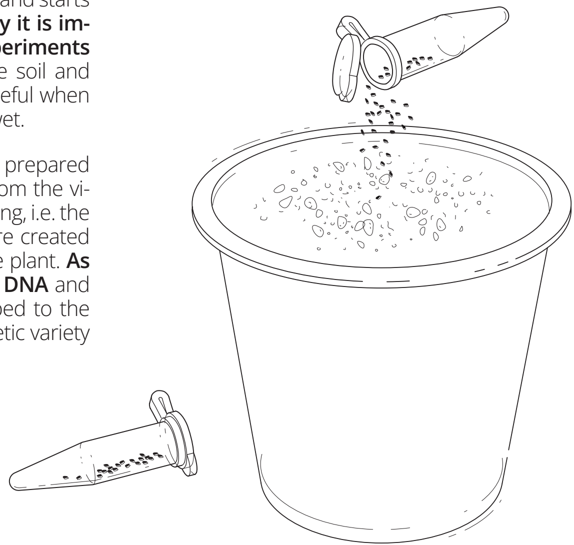
**Its genetic simplicity and easy handling have made Thale Cress a model for the study of plant genes and the mechanisms that control growth, development and interaction with the environment. It is basically an analogue to the white mouse that is so frequently used by zoologists**.

Scientists also appreciate Thale Cress due to its **ability to grow under a variety of conditions.** Its flexibility and resistance enable scientists to research how plants respond to various natural stresses such as drought, high and low temperatures or insufficient nutrients. Thale Cress also provides a valuable insight into **the adaptive strategies of plants**, which is critical for understanding how plants can survive and prosper in an ever-changing world.

**The fact that Thale Cress starts growing in spring in the wild means that its life cycle is influenced by the length of the day. Thale Cress devotes all its energy to leaf growth in spring when the days are shorter and thus increases size of its rosette.**

Later, when the days become longer, it switches its generative growth to the reproductive phase and starts forming flowers and later seeds. **That is why it is important to keep the day-length in the experiments in mind.** Thale Cress likes fresh and loose soil and does not do well in overly wet soil, so be careful when watering it and keep the soil damp, but not wet.

Researchers at the Institute of Botany have prepared **seeds of a single Thale Cress genotype** from the vicinity of Jihlava city for the AlbiLAB. The offspring, i.e. the seeds that you have available, were therefore created on the basis of the self-pollination of a single plant. **As such, all the plants have a near identical DNA** and any differences that you note can be ascribed to the experimental conditions and not to any genetic variety among the individual plants.



## COMPETITION

**Plants rarely grow alone. On the contrary, they very often have to come to terms with the presence of other plants of the same and different species and compete for elementary and often limited resources such as light, water and nutrients in order for them to prosper. This phenomenon where plant compete for limited resources is known as competition.**

In order for a plant to be successful in competition, it must be capable of **effectively using the available resources** and at the same time **resisting any negative influences** that may be caused by the neighbouring plants. For example, they may grow more quickly in order to reach the light before their neighbours or they may develop stronger root systems that enable them to have better access to the water and nutrients in the soil. Some plants can even release chemical substances into the soil that inhibit the growth of competing plants, a process known as allelopathy.

**The AlbiLAB kit will give you the opportunity to monitor the competition between plants from a front-row seat. You can, for example, set up an experiment where there is a single Thale Cress plant growing in one growth chamber**, i.e. in an environment without any competition, while there are several plants in the second chamber. You can decide for yourself how many there will be. **Experience from the Institute of Botany has shown that 20 or more plants can grow in the kind of container that you have available.**

This type of experiment will provide you with a deeper understanding of how plants interact with their environment and how competition influences their growth and development. As in all experiments with the Thale Cress, it is important to control the length of the day.

The day should be kept short, around 8 hours, during the first month so that the plants grow sufficiently.

You can then switch to a longer day (14 hours) in order to stimulate blossoming. Naturally, you can change the length of the day gradually, as this will be more natural for the plant.

You can combine this experiment with **varying degrees of light intensity** and can do so either in the way that we describe in the next experiment or after expanding the kit with a module enabling the separate control of the light conditions in the individual growth chambers. In this case, you can

have competing plants in both growth chambers, but each chamber can have a different lighting intensity.

Once you become experienced with regard to the light conditions that are optimal for Thale Cress, you can set up one chamber with optimum **lighting conditions** and a second with sub-optimum conditions to mirror the way that the degree of competition for a limited light source manifests itself in the plants' growth under differing light conditions.

The same procedure can also be applied with regard to the competition for nutrients where the plants in one chamber receive more nutrients (added fertiliser), while the plants in the second chamber will have their nutrients limited, because they will not be provided with any more.

## LIGHT INTENSITY

Light intensity **plays a critical role in photosynthesis**, the process during which plants transform light energy into chemical energy in the form of glucose which is then used as fuel for growth and other life processes. **Increased light intensity usually leads to a greater degree of photosynthesis**, which can increase the plant's growth speed, provided the other essential conditions such as sufficient water and nutrients are also met.

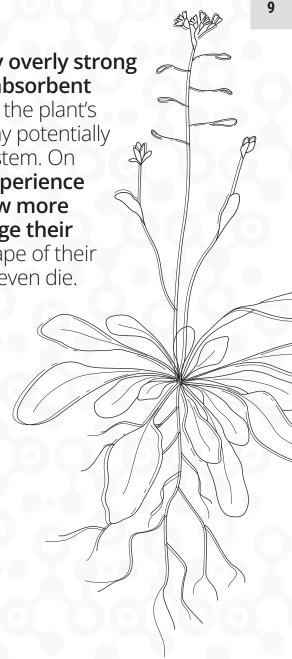
In nature, **plants that grow in the shade frequently face a lack of energy** which can stunt their growth and reduce their ability to reproduce. Such plants may also have smaller leaves and longer stems as they endeavour to reach more light.

Moreover, **the plants may not be capable of performing photosynthesis effectively, if the light intensity is overly low**, which can lead to an overall lack of energy and insufficient growth or even to their demise.

In this experiment, we will observe whether plants that are exposed to a higher intensity of light grow more quickly or on the contrary show signs of light stress.

**Light stress can be caused by overly strong light which may exceed the absorbent capacity of the chlorophyll** in the plant's photosynthetic centres and may potentially damage the photosynthetic system. On the other hand, **plants that experience a low light intensity may grow more slowly and significantly change their appearance**, especially the shape of their leaves and stems, or they may even die.

**This experiment will demonstrate how light is important for plant growth and how plants are able to adapt to different light conditions.**



## LIGHT INTENSITY

**It is possible to set up differing degrees of light intensity in the individual growth chambers by moving the light source away from the plant:** one growth chamber has a light ring located above the flowerpot (more intensive lighting), while the second chamber has a light source that is located one cube higher.

**There are smart phone applications that enable the measurement of light intensity, for example** Light Meter (Android) or Photone Grow Light Meter (Android, iOS).

This means that you will be able to have some idea of the difference in the lighting conditions in the individual growth chambers. **It is, however, necessary to keep in mind that the values measured in this fashion are only an indication and they depend on the type of the used application** and the type of device.

## LIGHT SPECTRUM

Research has shown that the RGB light spectrum (red, green and blue) significantly influences the different plant growth phases, including germination, vegetative growth and fruit production.

Any modifications to the RGB in the different growth phases may therefore optimise plant growth, fruit quality and the overall yield. Each phase has different requirements with regard to the light spectrum, which indicates that **the most effective approach may well be a dynamic lighting strategy that is adjustable throughout the course of the plant's growth**.

Here, you will learn how these phases are influenced:

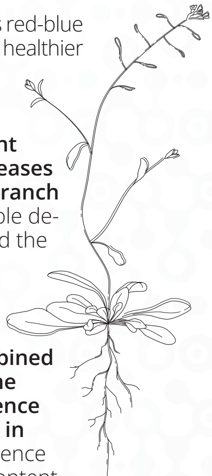
**The germination phase:**
**Red light increases seed germination and their early growth by supporting the faster and more effective hydration of the embryonic tissue, which leads to faster germination**.
(Zaghdoud et al., 2023)

**The vegetative growth phase:**
**White light combined from all the RGB components supports greater photosynthetic activity** in compari-

son with other light modes such as red-blue (RB) light, which contributes to healthier and better performing plants.
(Vitale et al., 2022)

It has been proven that **blue light reduces plant height, but increases robustness and changes the branch structure**, which may be desirable depending on the plant species and the specific growth objectives.
(Riikonen et al., 2016)

**The ripening phase:**
During the ripening phase, **combined blue and red light can delay the ripening of the fruit and influence the accumulation of nutrients in fruit** such as tomatoes and influence properties such as their sugar content, lycopene and β-carotene.
(Lee et al., 2023)



## HYDROPONICS

You are sure to have heard of the hydroponic cultivation of plants. Hydroponics is a **method of cultivating plants without the use of soil**, where the plants acquire **their nutrients directly from a mineral solution**.

The AlbiLAB includes zeolite, a mineral **substrate with a high absorptive capacity**, which is able to effectively hold nutrients and water and then gradually release them to plants, in addition to classic substrate for cultivating plants.

The advantages of hydroponics include **faster plant growth, higher yields, the more effective use of water and nutrients and the option of cultivating plants in environments where traditional agriculture would not be able to do so or only with great difficulty**. On the other hand, hydroponic cultivation is more demanding, **as it requires greater control over the environment** such as the pH, nutrient concentration and light conditions. It also involves initial investments in equipment and technology.

**You can experiment and compare the advantages and disadvantages of hydroponic cultivation compared to growing plants in classic substrate. Use**

**pre-dampened zeolite in one chamber.** You can immerse the pot in water up to its edge for several minutes so that the water gets into all of the pores.

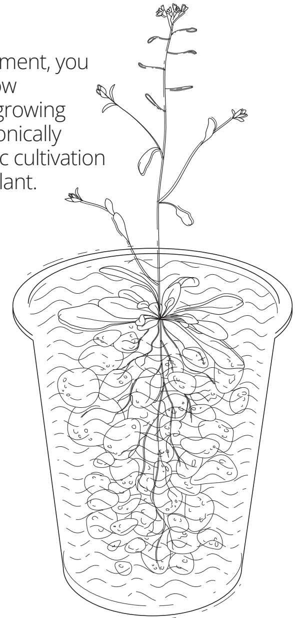
Ideally, the water should contain dissolved fertiliser: select the appropriate concentration according to the fertiliser instructions. (The fertiliser does not come with the kit).

Use the supplied substrate in the second chamber. Sow approximately 5-10 seeds into each chamber (when the plants germinate, sort the seedlings to find the strongest one) and set the day length (lighting period) at approximately 8 hours.

You can gradually adjust the length of the day so that the it is 14 hours long after approximately two months. Otherwise, you can keep the day short for a month and a half and then set a long day for the remainder of the experiment.

**Naturally, you can also let the plants grow with a shorter day for a longer period, even 2 months. This will create larger plants that will bear more flowers and fruit after being switched to a long day.**

At the end of the experiment, you will be able to assess how successful you were at growing the Thale Cress hydroponically and whether hydroponic cultivation is ideal for this type of plant.



# SOIL ACIDITY

One of the most common environmental problems that we come across is acidic soil, which is **caused by a variety of factors, including atmospheric pollution, the acidification of rainwater and the release of acidic ions** from a number of industrial and agricultural activities.

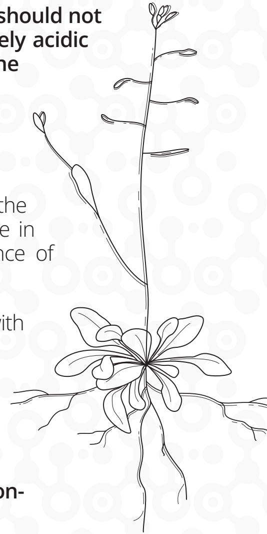
This phenomenal can have a distinct impact on the plant and the overall productivity of the ecosystem, because **soil acidity influences the availability of nutrients and toxic elements in the soil**.

**Plants have a variety of abilities for coping with soil acidity. Some plants, such as heathers or rhododendrons, can tolerate acidic soil well, while others, such as Thale Cress, refer a mildly acidic to neutral soil pH.**

The substrate supplied in the AlbiLAB kit has been prepared to have an **optimum pH for** cress growth (a pH of 5.5–6.5), which provides ideal conditions for its development.

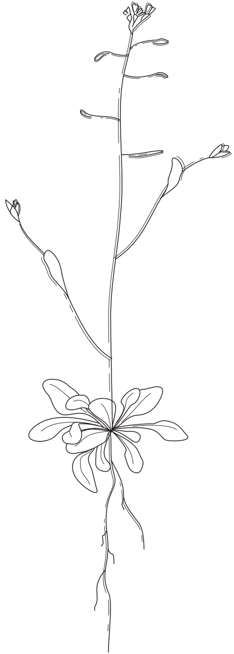
In this experiment, you can carefully acidify one of the flowerpots using regular vinegar and then **measure the resulting pH level using the pH strips provided with the kit.**

**It is important that the soil pH should not fall below 4.5, because extremely acidic conditions could be toxic to the Thale Cress.** You can then monitor how the cress responds to the acidic substrate in comparison to the optimum substrate.



The comparison may include the growth rate, the size or a change in the colour and overall appearance of the plants in both flowerpots.

This experiment will provide you with an opportunity to understand how **soil acidity influences plant growth and health** and will also acquaint you with **the importance of monitoring and maintaining soil pH to ensure optimum growing conditions.**

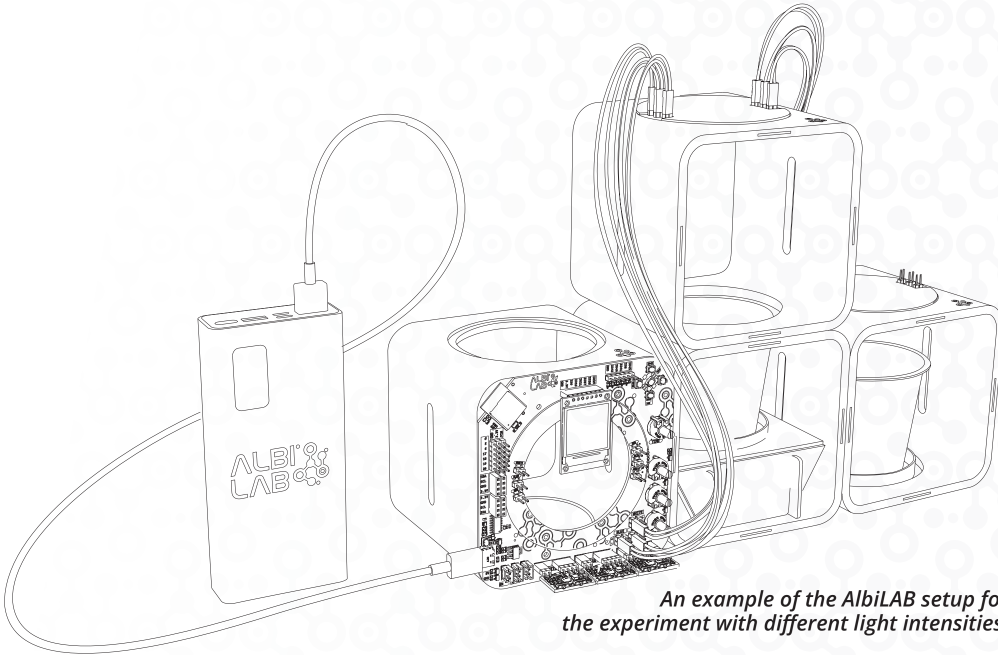


## SOIL SALINITY

As with the acidification of soil, its salinization is also a frequent environmental problem, especially in arid and semi-arid regions where the increased salt level in the soil may be caused either by natural processes or excessive irrigation.

Soil salinization also occurs due to the chemical de-icing of roads and other areas. **It can seriously influence the ability of plants to absorb water** even if water is readily available, which then leads to stress caused by insufficient water and **may significantly limit growth**.

As in the case of soil acidification, you can also use the AlbiLAB kit to simply **simulate the effects of soil salinization**. Pour a salt solution (brine) into one flowerpot and monitor how the Thale Cress responds to the increased salt levels in the soil in comparison to the plant in the control pot. **It is important that the salt concentration is sufficiently high** in order to simulate salty conditions, but not so high as to immediately kill the plant. It is possible to find out Thale Cress salt tolerance online. For example, seedlings can handle an NaCl concentration of approximately 125 mM, which very roughly corresponds to 7.5 g of NaCl per kilogram of soil.




*An example of the AlbiLAB setup for the experiment with different light intensities.*

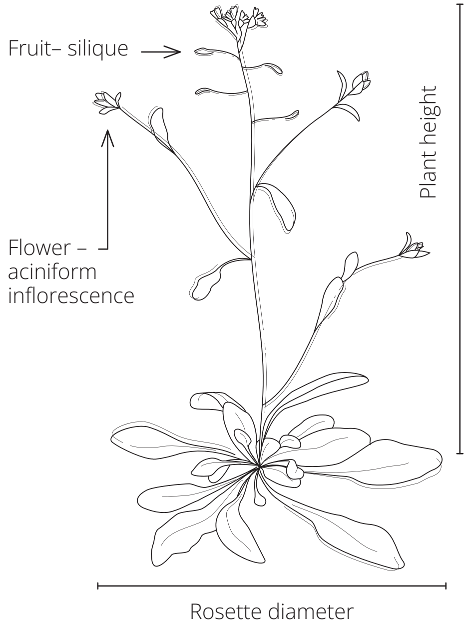
# WHAT TO MONITOR IN PLANTS

During the experiments, you can **monitor the plants' phenological response**, i.e. how many days it takes from sowing the seeds to the plants blooming or bearing fruit. You can also measure the growth rate based either on the number of leaves in the rosette, the length of the longest leaf or later the stem.

**You can most simply calculate the growth rate by comparing two values measured after a specific interval: the growth rate** = (the new value – the old value) / number of days. It is also possible to use more complex calculations enabling the use of multiple measurements over time. The samples and the tools can be found on the internet.

This non-invasive **measurement will provide you with the option of monitoring the plants throughout the course of the experiment.** If you have a precise set of scales available, you can cut the plant at the end of the experiment, dry it out and then weigh it.

**If the plants bear fruit, you can estimate their resulting condition or their biological (reproductive)** fitness **according to the number of created siliques.** This constitutes probably the most precise estimate as to how successful the plant has been and how many offspring it could theoretically have.



# EXAMPLES OF GROWTH RATE CALCULATIONS

## PLANT HEIGHT

Original height: 5 cm
New height after one week: 8 cm
Growth rate = (8 cm – 5 cm) / 7 days = 0.43 cm/day

## NUMBER OF LEAVES

Original number of leaves: 6
New number of leaves after a week: 10
Growth rate = (10 leaves − 6 leaves) / 7 days = 0.57 leaves/day

## ROSETTE DIAMETE

Original diameter: 2 cm
New diameter after a week: 4 cm
Growth rate = (4 cm − 2 cm) / 7 days = 0.29 cm/day

## AN EXAMPLE OF HOW TO RECORD THE MEASURED DATA IN GRAPH FORM