B1 Water cycle – Evaporation from plant leaves

This very simple experiment is ideally suited as an introduction to various topics. For example, it can be used in geography class to study the water cycle and the climate, and in biology class, to study water as the basis of life and its importance in plant metabolism. This experiment can even be used in physics and chemistry to present the states of matter using a real-world example.
The materials and apparatus supplied allow eight groups of students to conduct the experiments simultaneously.

1 Main question

How does the water cycle work? What role do plants play for the local climate? What role does evaporation during plant metabolism play? In the experiment, we will focus on the influence that temperature and specific plant types have on evaporation. In addition, the class should discuss the consequences that agricultural transformation and urbanization in the last 50 years have had on the basis for human life and the climate.

2 Integrating the experiment into the teaching context

2.1 Basic principles

The experiment covers a broad range, from basic scientific principles (evaporation as a phase transition, metabolism in plants) to the transformation in agriculture and consequences for the environment. The complex correlation between anthropogenic influences and changes in the natural basis for life can thus be introduced in school using an interdisciplinary approach based on a real example.
Special knowledge going beyond the general scientific knowledge of 14-year-olds is not required. The experiment's charm is that it combines all the previous knowledge and demonstrates how the different pieces can interact with each other.
However, if younger students do not yet know about the use of energy crops, for example, they can grow these plants themselves in pots and become familiar with them in this way. Further study (of cultivation areas, types of (mono)culture) can then build upon this.

2.2 Relevance to the curriculum

2.2.1 Students aged 11 years and up

Biology: The significance of cultivated plants, adaptation to climatic conditions
Geography: Changes in the Earth's surface by humans (farming and urbanization), measures to protect the Earth's surface

2.2.2 Students aged 12 years and up

Biology: Cell structure of living beings, plant metabolism
Geography: Climatic factors and consequences for the world of plants

2.2.3 Students aged 13 years and up

Geography: Vegetation zones

2.2.4 Students aged 14 years and up

Physics/chemistry: States of matter and their transitions
Geography: Agricultural production and the global market, based on examples

Topics and terms: agriculture, climate, cultivated plants, cuticle, environment, epidermis, evaporation, gas exchange, plant metabolism, stomata, temperature, water cycle

2.3 Skills

The students will …

- grasp the question of the experiment (What biological and climatic factors does transpiration in plants depend on?) and answer it by splitting the work among the groups.
- recognize the correlations (heat is needed for evaporation, not all plants evaporate the same amount of water) and record them in detail (lab reports).
- be motivated, possibly through the probing questions, to independently draw conclusions about the correlations from the knowledge of plant growth and agriculture they have gained from biology, geology, and everyday experiences, and to make judgments about the impacts of these correlations.

2.4 Explaining the experiment in the teaching context

Evaporation is vital for plants: Water and nutrient salts (and, depending on the season, also carbohydrates, etc.) are transported from a plant's roots to its leaves through the interaction of capillary forces (cohesion), osmosis, and, above all, transpiration suction. The plant can control the rate of evaporation, depending on the wind, humidity, and sun exposure:
Its leaves are covered on all surfaces by epidermal cells, which are protected by a layer of wax (cuticle) on the outside, making it hard for water vapor (as well as for oxygen and CO_2) to permeate the surfaces. Gas is exchanged with the environment through stomata. These stomata consist of two bean-shaped guard cells, which regulate the gas exchange of the leaf and thus can also control the evaporation rate in the range of two orders of magnitude.
Plants have adapted to climatic conditions. For example, cacti have a robust epidermal layer with a very thick cuticle and very few stomata. Tomato leaves are exactly the opposite, and therefore they need a lot of water.

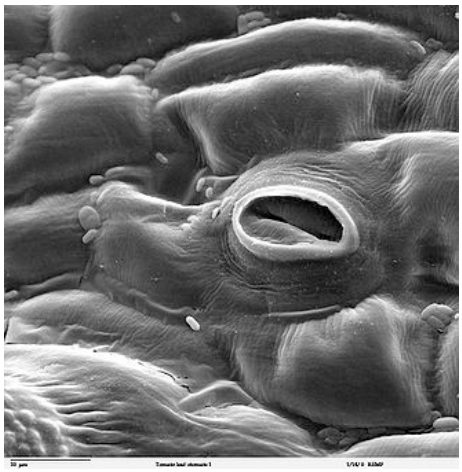

Fig. 1: Stoma on the leaf of a tomato plant.
Photo: Dartmouth Electron Microscope Facility

If plants are cultivated on a large scale, this especially impacts the water balance. These impacts can be discussed, for example, in geology class:

- Transformation of large areas by humans: clear-cutting and monocultures
- Destruction of the original biocoenosis of plants and animals, caused by the commercial use of nature by humans
- Rising demand for water, artificial irrigation
- Climatic changes on a local and global scale

2.5 Experimental variations

The experiment can be conducted quickly by all students; optimally, they will work in teams of two. Teachers should make sure that different plant samples are distributed to the groups – explain to your students that the differing observations will be compiled and compared.
Of course, the students can go on a field trip to collect the plant clippings themselves before they conduct the experiment.
You may also integrate the experiment into a teaching sequence on energy crops or monocultures – e.g., the students can grow plants from corn, rapeseed, soy, and sunflower seeds so that they can now use these plants.
Another option you have in this case is to assign report topics to individual groups, e.g., to present the observations from the experiments or to discuss the probing questions related to the experiments.
In this way, the students can present their results and, based on their abilities, broaden their knowledge.

3 Additional information on the experiment

You will find additional media for preparing or for further study of this experiment on the Siemens Stiftung Media Portal:
https://medienportal.siemens-stiftung.org

4 Notes on conducting the experiment

4.1 Facilities

The experiments require sun exposure. They can be conducted in the classroom or outside.

4.2 Time required

Realistically, teachers may need a double teaching period. The actual work is finished very quickly. Depending on the intensity of sun exposure or the lamp brightness and the ambient temperature, it may take an hour or longer for water condensation to appear. Teachers should use the waiting time to discuss the underlying teaching topic.

Preparation	Observation	Analysis	Discussion
10 min.	Up to 60 min.	15 min. together + homework	Can take place during the next class session; teacher may have individual students present their results as a report.

4.3 Safety aspects

The students may conduct the experiments only in the presence and under the supervision of the teacher.
The teacher is to point out to the students that the provided materials may be used only according to the respective instructions.

4.4 Apparatus and materials

Required materials that are not supplied:

- Clippings of leaves from different kinds of plants
  Note: The clippings should be dry on the outside so that you can be sure that the evaporated water comes from the plant itself.
- Clock
- Optional: a bright lamp as a substitute for direct sunlight (at least a 20-watt halogen reflector lamp).
- Optional: potted plants grown from seeds
- Optional: tap water, for cooling the cups
- Plastic wrap
- Soil

Supplied:
The apparatus and materials supplied are sufficient to allow **eight** groups of students to conduct the experiments simultaneously.
The following materials from the kit are needed for **one** group of students:

Material	Quantity
Digital thermometer*	1x
Bowl, aluminum	1x
Plastic cup (clear), 500 ml	1x

*Remove the plastic sleeve before the first use. Press the “on/off” button to turn on the thermometer. After completing the experiment, turn off the thermometer again (press “on/off” again). Press the “°C/°F” button to switch between the Celsius and Fahrenheit temperature scales.

Fig. 2: Apparatus and materials supplied for one group of students.

4.5 Cleanup, disposal, and recycling

All apparatus and nearly all materials from the kit can be reused. Therefore, after the students have completed the respective experiment, they should put the apparatus and materials back in the appropriate boxes and return them to the kit. This practice will ensure that you and your colleagues will find everything again quickly the next time the kit is used.
Apparatus that become dirty during the experiment, such as cups, bowls, spoons, and test tubes, should be cleaned before being returned to the kit. We recommend that you have the students do this immediately after they have completed the experiment.
Also make sure that the apparatus are in working order for the next time. For example, recharge used accumulators immediately (It makes sense to charge the accumulators even if they will not be used for an extended period.).
Materials that cannot be reused, such as used pH test strips and filter paper, should be disposed of properly.
The waste that accumulates during this experiment can be disposed of in the regular trash or poured down the sink.