

7. Plant evapo-transpiration

Goal of the task

This task deals with a specific aspect of plant physiology, together with clear physical implications. Students require access to a Texas Instruments CBL 2™ datalogger and Biology gas pressure, managed by a PC employing TII functionality.

A small sample branch with leaves (250-300 mm length, base diameter 5-6 mm) is connected to a small rubber tube, almost completely filled with water. The other end of the tube is inserted into the pressure sensor. The water that evaporates and transpires from the leaf surface produces a pressure drop and this is collected by the pressure sensor for a specified time period.

Through use of samples from different species or samples in different vegetative stages, or by simulating different environmental conditions (temperature, humidity, wind) it is possible to point out significant aspects of water balance in vegetables.

Target group and required time

The task is mainly targeted at students of 15-16 years of age (secondary school, 2^o-3^o year) who have the required prerequisite knowledge which is given below. The required time for the unit is:

- Two hours classroom lessons
 - Before the experiments: Task description, prerequisite knowledge check and remedial work
 - After the experiments: Discussion of the results and consideration of the issue.
- One/two hours biology lab session
 - Collection of data
- Two hours computer lab sessions
 - Processing and analysis of data
 - Lab report draft

Lab report draft and preliminary TI InterActive! skills

The students need basic computer skills, such as file management, word processing, printing and spread sheet skills. As far as TI InterActive! is concerned, students should be able to:

- use the Text Editor tools,
- use Quick Data tools,
- use the List Editor,
- calculate a regression equation,
- produce graphs of data and equations.

Specific skills for this unit include the ability to use the CBL 2, a TI-83 Plus and the Datamate application.

Preliminary knowledge of biology, physics and mathematics

The required preliminary biological knowledge includes:

- vegetal cell structure,
- foliar structure,
- functions of water in plants,
- structure and stomatic function,
- plant nutrition.

The required preliminary physical knowledge includes:

- changes of phase: evaporation,
- gas pressure.

The required preliminary mathematical knowledge includes:

- Understanding the meaning of a regression equation in a data series,
- Being able to interpret the graphs of a data series and regression equation.

File organization

The task consists of the following linked TII files:

- Notebook: the file in which the student writes the solutions. This is the starting point and contains hyperlinks to the other files.
- Main_Task: Contains the task for the students.
- Main_Task_Hint: Provides suggestions for the development Lab_Activity as well as information about the procedure to perform.
- Main_Task_Solution: Provides the Main_Task results and answers to the questions.
- Lab_Activity: Contains lists of requested materials and procedures.
- Lab_Activity_Hint: Provides suggestions for each stage of the lab activities.
- Control: Proposes some elements of reflection to verify if the task has been carried out correctly.
- Control_Hint: Provides support/help for the Control_Task.
- Control_Solution: Contains the Control task results and answers to the questions.
- Additional: Provides optional supplementary questions for students.
- Additional_Task_Hints: Provides suggestions for the Additional_Task.
- Additional_Task_Solution: Contains the Additional task results and questions.

The hyperlinks only work if the files are installed in the map c:\TII\Evapotranspiration. Students can start with the Notebook file in c:\TII\Evapotranspiration.

Classroom organization

To understand the meaning of the activity students have to know the role of evapo-transpiration with respect to water metabolism and mineral nutrition.

The task concerns an aspect of plant physiology and therefore it should be carried out in that particular disciplinary context. Initially it is necessary to discuss:

- the difference between evaporation and transpiration, and,
- conditions that influence evapo-transpiration process intensity.

During the experimental activity it is useful to set up groups of 3-4 students with different samples. Each group investigates how the assigned sample reacts to environmental conditions. Each group acquires data at room temperature and at a temperature of about 30°C (lit by a spotlight for a video camera).

The students' final product is a lab report, which can be evaluated by the teacher according to:

- Procedural correctness in experimental activity and data process,
- Completeness,
- Quality of answers to questions.

Technical hints

To install the task, double click on EVAPOTRANSPIRATION.TASK.exe file. Students can start with the Notebook file in the folder c:\TII\Evapotranspiration.

During the experimental activity it is possible to come up against the following difficulties:

- The sensor does not measure any pressure variation. The cause of this error can be:
 - an air bubble developed in the tube that links the sample to the pressure sensor.
 - an air bubble developed in the insertion point of the sample in the tube that links the sample to the pressure sensor.
- After several tests of data collection it is possible that the system pressure decreases and it can contrast with the sample “suction force”. In this case it is useful to disconnect the little tube from the sensor for a few seconds and then link it again.
- When you start data collection with QUICK DATA TOOL, an error message is often shown: “COMMUNICATION ERROR. VERIFY CONNECTION AND COMMUNICATION SETTING THEN RETRY”. When this happens it is often useful to select “Retry” a number of times to start data collection.

Didactical suggestions

Important aspects to point out during the results discussion:

- The process trend is the same in all groups independent of the type of sample. The samples have offered resistance to dehydration by starting a biological process of defence.
- The intensity of the evapo-transpiration process depends on the vegetative stage of the sample. In spring/summer time the process is generally more intense than autumn/winter time.

As a development activity students could test different environmental conditions to point out particular reactions of some vegetable species.

7.1 Main task

intro

Water metabolism is a fundamental part of plant physiology. Water, by cell's turgidity, performs structural functions as well. All plants wither when water metabolism is lacking. When this variation occurs for a long time plants shrivel up and die. In addition, plants satisfy the need for mineral nutrition by water metabolism. Root apparatus, absorbing the circulating solution of the soil, allows plants to soak up macro elements (N, P, K, S, Ca, Mg, Fe) and microelements (B, Mn, Cu, Zn, I).

The term Evapo-transpiration indicates two concomitant processes: the evaporation of a physical type and the transpiration of a biological type.

Transpiration is a complex process founded on delicate self-control systems. The excessive transpiration of the plant damages the cellular turgidity while insufficient transpiration depresses the mineral nutrition and therefore the growth of the plant.

Stomata opening, the basis of the process of transpiration, is also justified by the need of the plants to absorb and metabolize CO₂ through the photosynthetic process.

Transpiration can take place through the cuticle, the stomata and the lenticelles. Stomatic transpiration is the most important process because it assures the plant of necessary water flow.



Picture 1: *Pothos aureus* L - Stoma with chloroplastis.

In this experiment we want to compare the necessity of water for the different plant species, Laurel (*Laurus nobilis* L.), Lemon (*Citrus lemon* L.), Olive (*Olea europaea* L.) and Orange (*Citrus sinensis* L.) under constant environmental conditions.

The deduction is indirect. The sample evapo-transpiration is evaluated through the measurement of the drop in pressure and so evapo-transpiration is collected and measured by a pressure sensor.

It would be correct to correlate pressure variation with leaf surfaces actually transpiring; but, to simplify the experiment we will correlate pressure variation – due to the water loss – with the sample mass.

task

Hint 1

- a. Complete the lab activity. For a description click on the Lab procedure link at the bottom of this page.
- b. Process the data:
 - (i) For each data set calculate the absolute value of pressure with reference to the starting value.
 - (ii) Produce and label a graph for each new data set.
 - (iii) Create a new list to relate the pressure to the sample mass.
 - (iv) Create a new list to relate the pressure to 100 cm² of leaf surface.
 - (v) Graph the results.
 - (vi) Calculate regression equations for the new data sets (related to the sample mass). To do this you will need to select an appropriate regression model, insert the results into the opened document and modify the equations so that the curves pass through the origin. Graph the regression equations.
- c. The process of evapo-transpiration shows the same trend in both conditions? How can we define it? Is it stationary, increasing or decreasing? Explain your comments.
- e. In which condition has the highest evapo-transpiration activity been recorded? Explain why you believe this is the case.
- f. How does the evapo-transpiration process evolve in the two tested conditions?
- g. Calculate the ratio between the two data sets of drop in pressure, relative to the highest and lowest intensity recorded for the evapo-transpiration.
- h. Give an explanation of the results both for the physics and biological aspects.

7.2 Additional task

task

Hint 2

- a. Copy data collected by another group into your Notebook file .
- b. Process the other group's data as requested in the Main Task file (Data processing).
- c. Compare the results of the two samples (your own data and the data of the other group) and write a reflection on the similarities and differences.

7.3 Control task

task

Hint 3

- a. Describe the trend in the graph (point 1 of “Process data” in Main_task) without using the absolute value of pressure.
- b. In this case what is the relationship between pressure and loss of water due to the evapo-transpiration process?
- c. How does the trend observed in the graph change (points 2 and 4 of “Process data” in the Main Task) after you have correlated the sample mass to the pressure? Compare your results with the findings of other groups.
- d. Explain how you can modify the regression equation so that it will pass through the origin. Find this regression equation. Compare your results with other groups' findings.

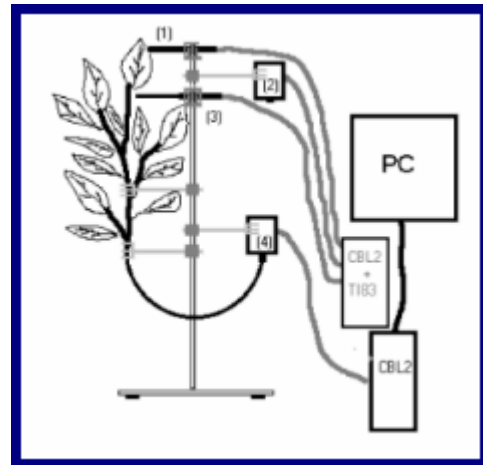
7.4 Lab activity

lab _____

Requested materials

- Gas Pressure Sensor
- Light Sensor Vernier – Range 6000 Lux
- Relative Humidity Sensor Vernier
- 1 ring stand with rod
- 2 adjustable clamps
- a PVC wash bottle with distilled water
- silicone grease for dryers
- spot for video (IANIRO 800 W Mod. 190MK1)
- 2 CBL 2 data loggers
- 1 TI-83 Plus SE
- PC with TI InterActive! installed

Experimental apparatus



1 - Light Sensor 2 - Relative Humidity Sensor
3 - Temperature Sensor 4 - Gas Pressure Sensor

- Prepare experimental apparatus as represented in picture.
- Start DATAMATE (software to control CBL 2 system) on your TI-83 Plus graphic calculator. and set the Relative Humidity Sensor (not auto ID). Read and record the values for brightness, relative humidity and temperature.
- Set TI InterActive! for data acquisition in QUICK DATA TOOL mode by selecting:
 - * sensor: **Pressure sensor**
 - * number of samples: **60**
 - * collection interval: **5 s**
 - * x-List: **Time**
 - * y-List:
 - test 1: **Pressure**
 - test 2: **Pressure1**
- Collect data. Environmental conditions:
 - * room temperature, lowest brightness conditions,
 - * temperature not over 30°C, brightness about 5000 Lux, (using spot for video, placed at right distance from sample).
- Transfer collected data to Notebook file.
- At the end of measurement defoliate the sample, weigh leaves, record their mass and estimate the total leaf surface area (using a piece of graph paper).

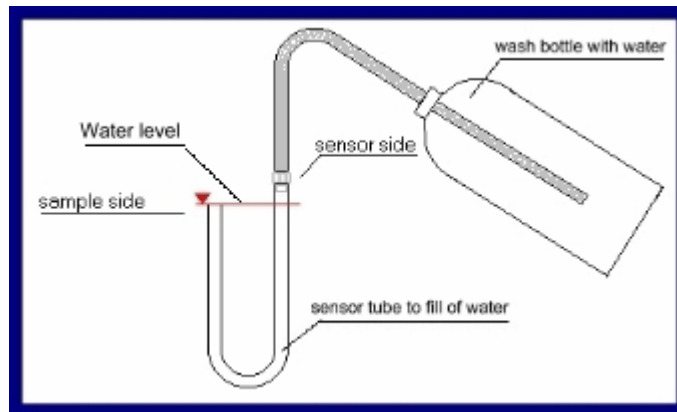
7.5 Hints

hint 1

a. Do the lab activity

Preparing Experimental Apparatus

- To ensure correct water flow to the sample, make a clean, oblique cut on the sample bottom, and place the sample into the little sensor tube, previously filled with water.
- When filling the sensor tube with water be careful to position the tube as shown in the picture below. It is important to avoid air bubbles forming while filling the tube.



- On the side of the sensor the tube must be empty for a length of 10 mm. You can do this by pressing the end of the tube (sensor side) with your fingers after having inserted the sample in the other side of the tube.
- Check that there aren't air bubble along the tube.

Data collection

- In the Notebook file open LIST EDITOR.
- If it is necessary to repeat the data collection test several times then it is advisable to disconnect the little tube from the sensor for a number of seconds, and then link it again.
- When you start data collection with the QUICK DATA TOOL, an error message is often shown: "COMMUNICATION ERROR. VERIFY CONNECTION AND COMMUNICATION SETTING THEN RETRY". If this happens, it is often useful to click "Retry" a number of times to start data collection.
- To measure the leaves surface area group (by superimposition) those with the same dimensions. For each group trace the contour of a leaf on a piece of graph paper. Estimate the leaf surface using the drawing. Calculate the leaves surface for the group's sample.

b. (i) Calculate the absolute value

Use the function **abs()**.

b (ii) Show the graph of each new data set

Use the the Graph Editor and Label option in the Draw menu. Refer to the Manual for more information.

b (iii)-(iv) Create a new calculated list

To calculate pressure variation per gram or to relate the pressure to 100 cm^2 of leaf surface, label a new list and insert a suitable formula.

b (v) Show the graph of results

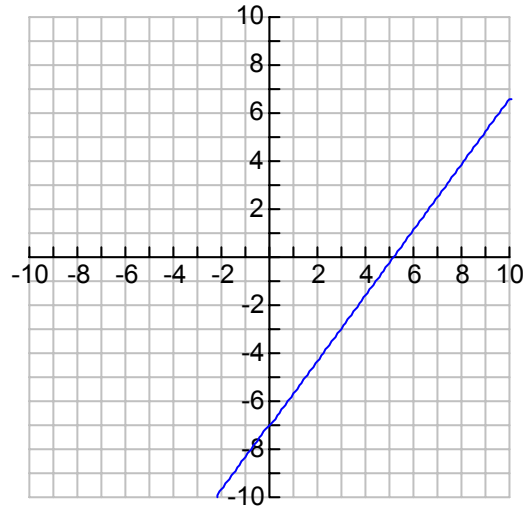
Refer to step 2.

b (vi) Calculate regression equations

To calculate the regression equation use the Stat Calculation Tool and choose the appropriate regression model (look at the graph before selecting a model). To modify the equations to pass through the origin follow the steps in the following example. You can modify the linear graph by changing the value of the coefficients **m** and **n**.

define $f(x) = m \cdot x + n$

m: n:



- c. Consider the trend in the graph.
- d. The Stat Calculation tool offers many statistical variables useful to evaluate the results.
- e. Compare the trend of pressure variation in the final graph.
- f. Use the two angular coefficients of the regression equations.
- g. For physics aspects you can correlate the experimental results to the evaporation phenomenon. To explain the biological aspects you can refer to the stomata activity and working of stomata opening.

hint 2

- a. Describe the trend that you expect to appear in the first graph if the pressure variation is negative.
- b. Reread the introduction section in the Main Task file. It explains the way in which the pressure sensor measures the sample loss of water. If the phenomenon increases, how does the pressure measured by the sensor change?
- c. Compare the graphs that were produced for points 2 and 4 of the data process. Describe any significant changes observed. Can a different mass for the sample (greater or less) modify the trend of the second graph with reference to the first? Is it important to correlate the pressure variation to the sample mass? In order to compare the results of different samples, do you think that it is important to take into consideration the mass difference?
- d. In the Main_Task file it is suggested that you may find it necessary to verify the meaning of the coefficients **m** and **n** into the equation $f(x) = mx + n$. If you have difficulty to answer, you can reread this point and then try to represent a graph using the regression equations without arrangement.

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