Investigating Transpiration

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Background:

Water is used by plants for maintenance and growth. Movement within the plant is through the vascular tissues that conduct water against gravity. The specific water needs of plants are dependent on environmental conditions and the metabolic activity of any given plant itself.

While water is used for metabolic activities and for maintaining osmotic regulation, a large amount is lost by the plant on a daily basis. Water loss from the plant occurs mainly by two basic processes of transpiration and guttation. The loss of water from aerial parts of the plant through openings called stomata is called **transpiration**. The loss of water from leaf margins is called **guttation**.

In vascular plants, water enters the xylem tissue of the roots through extensions of the root epidermal cells. These extensions are called root hairs. The movement of water into the xylem occurs by osmosis and this movement creates what is termed root pressure. Root pressure can only force water up a short distance. Since a plant can be tall, the root pressure is often not sufficient to force water up to the leaves of the plants; therefore, another mechanism must be in play also. This mechanism is defined by the cohesion-tension model of xylem transport. If the water lost by a plant through transpiration and guttation is not replaced, then the plant will wilt and eventually die. Here the water lost due to transpiration is linked to the active area of leaves from where transpiration process occurs.

Your task is to calculate the amount of water lost by the plant per ~~square area~~ unit area of the leaf.

You are supplied with the following:

Materials	Annotations	Quantity Supplied
1. Simple potometer	**SP**	1
2. Syringe [20 ml]	**SY**	1
3. Plastic Tray	**PT**	1

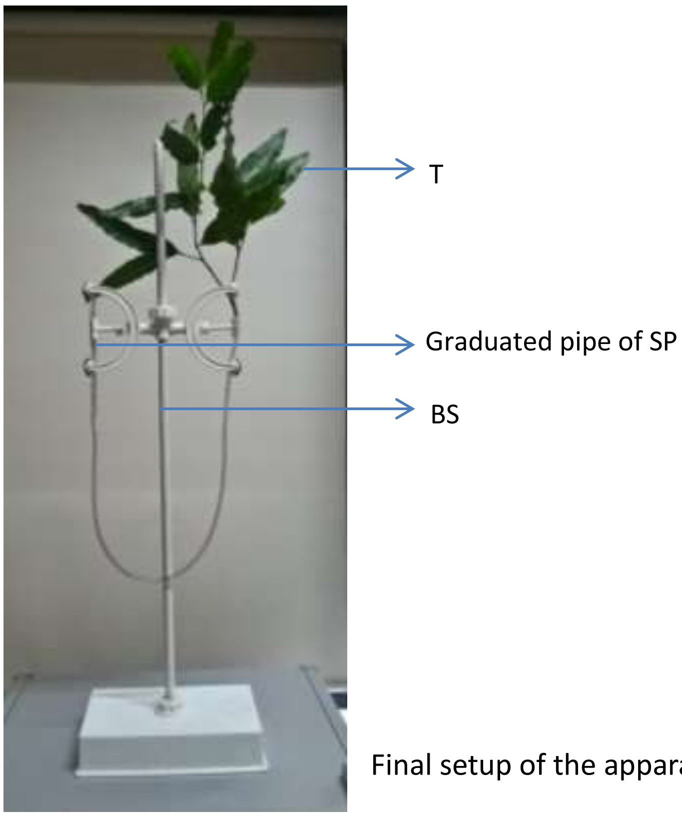
4. Water		As supplied in the tray
5. Liquid colour	**LC**	1 bottle
6. Scissor	**SC**	1 pair
7. Parafilm	**PF**	1 large strip
8. Stop watch	**SW**	1
9. Burette stand	**BS**	1
10. Dropper	**D**	1
11. Oil in a tube	**O**	1
12. A twig	**T**	1 in a conical flask

Procedure: [X marks]

1. The **SP** has two ends; one with graduated pipette and another having flexible tube opening. The twig **T** will be attached to flexible tube end by following method:
2. Fill the tray, **PT** with coloured water and completely immerse **SP** into the water such that no part of **SP** floats on the water. Put some weight on **SP** if necessary.
3. Keeping **SP** below water, take the syringe, **SY** and fill coloured water through the tube end. Make the water flow out of pipette end by repeatedly filling it through tube end with the help of syringe (syringe should be attached to the tube end). This is to ensure that there are <u>no bubbles</u> trapped inside the pipe.
4. Let water filled **SP** stay submerged. In the meanwhile, take the twig **T,** check if it fits firmly in flexible tube end of **SP.** If it is fitting loosely then wrap the twig approx. 1 inch above cut end with parafilm **PF** strip to make it thicker in diameter.
5. Cut the twig <u>underwater</u> in a slanting angle just below the wrapped parafilm with the help of blade and immediately insert it into the tube end of **SP** and fit tightly.
6. Take out the whole setup from water and fix it on the burette stand with pipette end placed at little higher level than tube end (with fixed twig).

(Ensure that the setup does not leak from anywhere. Ensure that the twig is properly fixed at tube end. Wrap parafilm around it to ensure there is no airspace at the joint. If it starts leaking, the water level in pipette will start dropping immediately. In such case, remove the setup and repeat steps 3, 4 and 5.)

7. Ensure that both ends of the tube are aligned (as seen in Figure below).
8. Put a drop of oil on the water at the graduated end of the SP. Keep your setup under the fan and in ample light condition.



Final setup of the apparatus

9. The water level in pipette starts decreasing gradually. Start the timer when water level reaches the first mark on pipette. Stop the timer when it reaches next mark. Record the time (t). Immediately reset the timer and start again for next reading. Take 5 consecutive readings in a same way. The distance between two marks indicates 0.1 ml volume of water. The (t) is the time taken by plant for transpiration of 0.1 ml water. Take average of all 5 readings.
10. Tabulate your data in the table **A1** given below (in your answer paper) [X marks]

Table A1

Readings	Time (min: sec)
1	
2	
3	
4	
5	
Average (t)	

11. Calculations:

i) Take an average sized leaf and draw its outline on a graph paper.

Calculate its area. [X mark]

ii) Calculate the rate of transpiration per minute. [X mark]

iii) Calculate the rate of transpiration per unit time per unit area.

[X mark]

[Some questions based on the experiment that can be used to make student appreciate the process and make conceptual connections.]

Questions:

1. Why do you think we put the oil drop on the graduated side of the SP. [X mark]

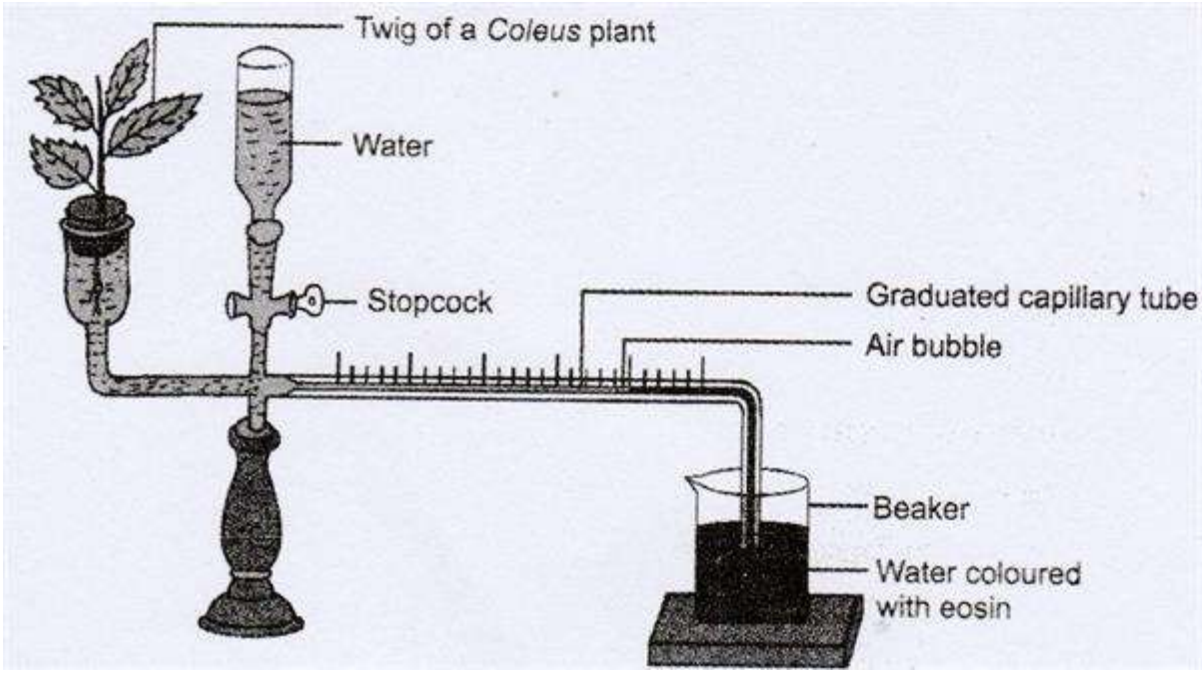
2. Why did we cut the twig **T** below water? [X mark]

3. The average transpiration rate of a potted *Coleus spp.* plant at 35% humidity and STP is 0.71 g/dm^2/hr. What will happen to the rate of transpiration and the condition of *Coleus* plant under the following conditions: [1.5 mark]

Environmental Condition	**Rate of transpiration**	**Condition of potted plant**
Sunny, humidity 98%, soil well watered	Increase/decrease/remains same	Straight/wilted
Sunny, humidity 65%, soil dry	Increase/decrease/remains same	Straight/wilted
Windy, humidity 65%, soil well watered	Increase/decrease/remains same	Straight/wilted

4. Which anatomical structure in plant leaves is responsible for guttation?
[Y mark]

5. During early winter mornings, you often see water droplets accumulated on top of leaf blades and at the margins. The drops might be dew drops or guttation water. How would you (chemically) distinguish between the two? [X mark]



(i) What is the name of the apparatus? [X mark]

(ii) What is the purpose of water in the reservoir? [X mark]

(iii) What will happen if the *Coleus* twig is replaced by Cactus twig? [X mark]

(iv) What will happen to the position of air bubble under the following conditions: [1.5 mark]

(a) In dark
(b) In sunlight

(c) In front of the fan

6. Mention one limitation of the apparatus used by you. [X mark]

The experimental protocol described above is one of the most foundational one in plant physiology, commonly carried out in schools and at the graduate level. When we introduced the experiment, we were considering two areas of change: (a) a different experimental set-up than potometer that can be easily designed for school labs; and (b) changing parameters in order to help students think about causal change.

(a) Alternative set-up: Often availability of specific lab equipment poses a challenge. We wish to develop and present an alternative design of the experimental set-up that is reasonable and allows students to extend their imagination beyond routine laboratory set-ups (see figure below).

(b) Regulating parameters to study causation in students' thinking:

While in protocols, evident change in environmental conditions is discussed, we wanted to explore other implicit parameters (often not discussed), such as follows:

(i) Length of the twig
(ii) Different leaf size but the same twig
(iii) Different anatomical structure (e.g. twigs of different plant species – herbaceous, woody shrub, climbers, hydrophyte, halophyte, xerophyte, etc.)
(iv) Covering the leaf surface with gelatin or parafilm and studying the order of change
(v) Transforming the twig itself by breaking of some number of leaves from the twig base and covering the exposed part of stem with parafilm

It is through the changes on these two broad areas that we see the potential of the experiment in helping students make a coherent conceptual connection with leaf area, surface area of stem and the process of transpiration.