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Investigating the relationship between the transpiration rate of a shoot and the degree of opening of the stomata of its leaves

I will be investigating the relationship between the transpiration rate of a shoot and the degree of opening of the stomata of its leaves.

Transpiration is the loss of water vapour from the surfaces of a plant. Solar energy turns the water in the plants into a vapour causing it to evaporate into the leaf's internal air spaces before diffusing out of the stomata into the air. The water is able to evaporate out of the leaf as the leaf has a high water potential and the surrounding has a low water potential. The water molecules pass down the concentration gradient from the spongy and palisade mesophyll cells into the leaf's internal air spaces before diffusing out into the air.

For this experiment, I will need to vary a factor that affects both the transpiration rate and the degree of stomata opening in order to determine the relationship. Factors that affect transpiration rate are humidity, temperature, light intensity, water supply, plant surface area, plant species and wind speed. These in fact affect both incidents because transpiration rate depends upon stomata opening to allow gas exchange. Using the apparatus available in a school laboratory, I will determine the relationship by varying the **wind speeds**, hence, keeping all the other variables mentioned above constant. The reason for choosing wind speed is because none of the other factors can be kept mutually variable for reasonable results (i.e. if light intensity is chosen as a variable, the temperature will fluctuate as well).

In the control test where there will be no wind, water vapour will be able to build up in the air spaces of the leaf and form a layer around the leaf as water transpires out. This will reduce the water potential gradient between the inside and outside of the leaf. This will in turn reduce the rate of transpiration. If wind blows across the leaves, this layer of water vapour will be blown away. The water potential gradient between the inside and surroundings of the leaf will increase and so the rate of transpiration at this point will increase. Leaves can lose water through their upper epidermis but they generally lose more through their lower epidermis where there are more stomata.

"*W*hen the air starts to fill with water vapour the humidity starts to affect the plant. The plant can only diffuse water vapour through the stomata if the leaf cells contain more vapour pressure then the air outside. If the air is humid the rate of transpiration decreases rapidly. *W*hen the wind is acting on the air around the plant it transports the molecules away, decreasing the vapour pressure in the air.**"**

(Biology, Exploring Life; *W*iley)

My hypothesis is that as I increase the wind speed, the plant will adapt to the environment (assuming only air current is limiting) and will hence increase the transpiration rate. By doing so, the stomatal density will increase to allow optimum transpiration.

The species of plant that I will use will be a pure-bred red hot poker plant *K*niphofia (monocot). I have chosen this because, from research (www-saps.plantsci.cam.ac.uk), it tends to have highly ordered stomata in rows which are big enough to be clearly seen with a light microscope to aid in observing the stomata.

Method

I will use the following methods:

- A potometer for observing the rate of transpiration
- Nail varnish impressions for observing the degree of stomatal opening

I will need:

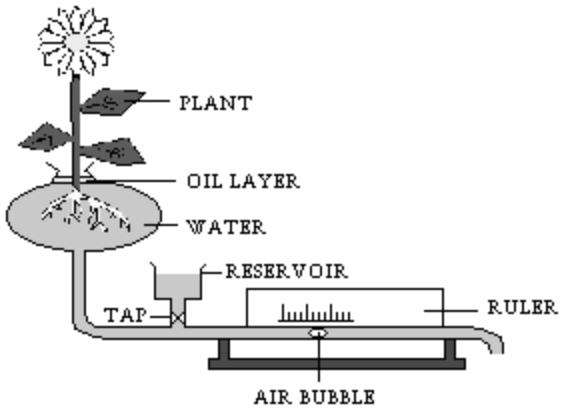
- 30 small , individual *K*ni*phofi*a *p*lants
- lamp (light source)
- potometer
- fan
- ruler, pencil, calculator
- stopwatch
- nail varnish
- microscope, slides and cover slips
- Forceps

Using 10 of my plants, I will use an increase in distance of a fan from the plant as my increase in wind speed. I will repeat this two more times (hence the need for 30 plants). The reason for choosing individual plants to work on instead of just one is so that the experiment will be a fair test. I.e. if I choose one plant and start cutting shoots from it, it will gradually affect the overall transpiration rate.

It is not easy to measure the rate of transpiration but I can use a potometer to measure the rate of water uptake. I know that the amount of water loss is less then the water taken up by the roots as some of the water is used for photosynthesis (Biology 1, Cambridge Press).

I will move the fan 20cm at a time until the fan is 200cm away, starting with a 20cm distance.

I will keep the plant in this situation for 5 minutes so that it adapts to the environment. I will then stop the fan and proceed to measuring the rate of transpiration as follows:



1. First I shall fill the capillary tube by submerging it in water.
2. Next I will cut the end of a *K*niphofia shoot under water.
3. I will attach the shoot to rubber tubing connecting the plant to the capillary tube.
4. I will have to attach a ruler near the glass tube to measure the distance travelled by the air bubble.
5. I will start the fan on the chosen distance (starting from 100cm) and leave it there for 5 minutes for the plant to equilibrate.
6. To make an air bubble I shall have to take the glass tube out of water and rub the end to remove excess water. When I place the tube in water I shall be able to view an air bubble.
7. I will start the stopwatch for 2 minutes. Then I will measure with the ruler the distance travelled by the bubble during that time.
8. I will record this on a table similar to the one below.
9. I will repeat this twice more for the same distance (wind intensity)
10. I will repeat steps 1-9 for the next set of wind intensities.
11. To find the transpiration rate I will do **volume of water uptake/time**
    I will measure the volume of water uptake using the following formula:

    $V = \pi \times (\text{radius of capillary tube})^2 \times \text{distance of air bubble traveled}$

    Volume in mm^3, time in min therefore the rate of transpiration in $mm^3\ min^{-1}$

Now, from the same plant for each wind intensity, I will measure the density of open stomatal pores:

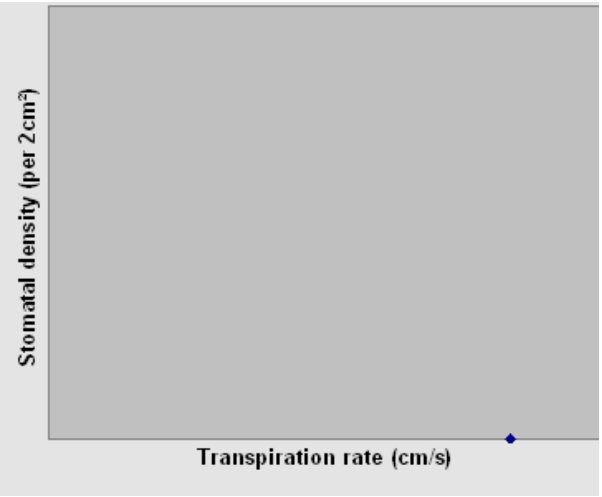
1. I will clip 3 leaves from the same plant.
2. I will paint the bottom surfaces, **2cm by 1cm**, with clear nail varnish making sure the leaf is **dry** (otherwise, from past experience of this test, the cast will not be clear to see [contact Mrs. J Smith for reference]).
3. Allow varnish to dry, 10 minutes.
4. Use forceps to carefully remove the cast.
5. Adhere (used thesaurus) to slides and apply a cover slip.
6. Using the whole area under a magnification of (x10) and the 2cm by 1cm, observe the visible open stomata and count them and record the number on a table similar to that below.
7. Repeat for the remaining three leaves and find the **mean** density.

I will repeat this procedure for the remaining 9 results (at 4cm, 60cm, 80cm… 200cm). I believe these measurements are appropriate to carry out an efficient investigation.

	Distance travelled by bubble in mm					

	Trials					
Distance of fan in cm	**1**	**2**	**3**	**Average**	rate of transpiration $mm^3\ min^{-1}$	**Mean Stomatal density**
20						
40						
60						
80						
100						
120						
140						
160						
180						
200						

After collecting results, I will plot them against a graph as follow and then use statistical analysis to observe any **correlation** between the two factors to prove my original hypothesis:



Summary

To make the investigation a fair test, I will only have one variable, the distance of the fan. I will be doing three sets of trials all using the same apparatus. By repeating the experiment I will be able to collect reliable results. While doing the experiment I will need to take a few precautions. When I am placing the *Kniphofia* shoot into the rubber tubing I will try not to bruise the xylem cells, as this will affect the plants uptake of water. If that happens I cannot keep the uptake of water consistent.

This plan is as precise as possible. However, water is used up in photosynthesis, but this should be at a constant rate so would not affect the increase in the uptake of water (I already know that the graph is not going to go through the origin, so it will just affect how far up the y-axis it starts). It also will be fairly inaccurate as it is not easy to read how far the meniscus has travelled to any degree of accuracy smaller than 1mm, but yet this will have a large effect on the results, and 0.5mm could be as much as 5% of the distance travelled, this inaccuracy would then be multiplied by the area of a cross section of the capillary tube. It would not be very easy to improve this, unless I use a very accurate ruler, and a magnifying glass, but this seems unnecessary, as the inaccuracy would not make that great a difference to the graph.

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references are highlighted in blue

Word count = 896 words