

Temperature, wind speed and transpiration

Investigate and describe the effects of variation of temperature and wind speed on transpiration rate

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). Teacher answers start on a new page.

Name

Date

Aim

To investigate how wind speed and air temperature affect the rate of water uptake, and so the rate of transpiration, of a leafy shoot using a potometer.

Background

Transpiration is the loss of water vapour from the leaves. Water evaporates from the surfaces of the mesophyll cells into the air spaces and then diffuses out of the leaves through the stomata as water vapour.

A **potometer** measures how much water a cut shoot takes up. Most of the water taken up is lost by transpiration, so the rate of water uptake is used as an estimate of the rate of transpiration. As the shoot takes up water, the air bubble in the capillary tube moves along the scale towards the shoot.

A higher temperature gives a faster rate of transpiration. A higher wind speed also gives a faster rate.

Supplement: at a higher temperature water evaporates from the mesophyll cells faster and water vapour diffuses faster. Moving air blows away the water vapour near the stomata, which keeps the **concentration gradient** steep.

Hypothesis

The rate of water uptake will increase as wind speed increases and as air temperature increases, because water vapour is lost from the leaves faster.

Variables

Independent	Part A: wind speed, changed by the distance of a fan from the shoot (no fan, 100 cm, 50 cm, 25 cm). Part B: air temperature next to the leaves, changed by the heat setting of a hair dryer clamped at a fixed distance (cool, low heat, high heat).
Dependent	The distance moved by the air bubble in 5 minutes, used to calculate the rate of water uptake in mm per min
Control	• The same leafy shoot (same number and size of leaves) throughout • Light intensity: the same position in the laboratory with the same lighting • Part A: the same fan speed setting and the same air temperature • Part B: the same distance of the hair dryer from the shoot (50 cm) and the same fan speed setting, so the wind speed stays the same • The time for each reading (5 minutes) and the time left to settle (5 minutes)

Equipment

- Potometer (reservoir with a tap, capillary tube with a millimetre scale, and a holder for the shoot)
- A leafy shoot about 25 cm long, for example from privet, geranium or willow
- Bowl or sink of water, large enough to assemble the potometer under water
- Secateurs or a sharp knife, and a white tile
- Petroleum jelly
- Paper towels
- Electric fan with a fixed speed setting
- Hair dryer with a cool setting and two heat settings, held in a clamp and stand
- Metre rule
- Thermometer, -10 °C to +110 °C
- Stop-clock reading to 1 s or better
- Beaker of water for the end of the capillary tube
- Tray to catch spills

Risk assessment

Hazard	Risk	Precaution
Cutting the shoot with secateurs or a knife	Cuts to the hand.	Cut on a white tile, away from the body and fingers.
Water near the fan, the hair dryer and their plugs	Electric shock if water spills on to mains equipment.	Stand the potometer in a tray, keep the fan, hair dryer and cables away from the water, and clear spills at once.
Hot air and the hot nozzle of the hair dryer	Minor burns.	Clamp the hair dryer so that it is not held by hand, do not touch the nozzle, and switch it off when it is not in use.
Glass capillary tube	Cuts if the glass breaks.	Handle it with care and report any breakage to the teacher.

Method

1. Cut a leafy shoot under water, at a slant, so that no air enters the xylem.
2. Assemble the potometer under water so that it is full of water, and fit the cut end of the shoot into the holder under water.
3. Lift the potometer out of the water, stand it in the tray and check that it contains no air bubbles. Seal the joints with petroleum jelly so that they are airtight.
4. Dry the leaves gently with a paper towel.
5. Lift the end of the capillary tube out of the beaker of water for a moment to let one air bubble in, then put it back into the water.
6. Use the reservoir tap to move the bubble to the start of the scale.
7. Part A: with no fan, leave the shoot for 5 minutes to settle. Measure the air temperature next to the leaves. Record the position of the bubble, start the stop-clock and record the position again after 5 minutes.
8. Move the bubble back to the start with the reservoir and repeat the 5-minute reading twice more, so that you have three readings.
9. Switch on the fan 100 cm from the shoot. Leave the shoot for 5 minutes, then take three 5-minute readings as before. Repeat with the fan 50 cm and then 25 cm from the shoot, keeping the fan on the same setting.

- L0 . Part B: switch off the fan. Clamp the hair dryer 50 cm from the shoot, pointing at the leaves, and switch it on at the cool setting.
- L1 . Leave the shoot for 5 minutes, measure the air temperature next to the leaves, then take three 5-minute readings.
- L2 . Repeat step 11 with the hair dryer on the low heat setting and then on the high heat setting. Do not move the hair dryer or change its fan speed.
- L3 . Calculate the mean distance moved for each condition.
- L4 . Calculate the rate of water uptake for each condition using: $\text{rate} = \text{mean distance moved} \div \text{time}$.
- L5 . Plot a graph of the rate of water uptake against each independent variable.

Results

Distance moved by the air bubble in 5 minutes							
part	distance of fan or hair dryer from shoot / cm	air temperature next to leaves / °C	distance moved by bubble / mm: 1	distance moved by bubble / mm: 2	distance moved by bubble / mm: 3	mean distance moved / mm	rate of water uptake / mm per min
A (no fan)	-						
A (fan)	100						
A (fan)	50						
A (fan)	25						
B (cool setting)	50						
B (low heat)	50						
B (high heat)	50						

Graph

Two line graphs. Graph A: distance of fan from shoot / cm on the x-axis (25 to 100) and rate of water uptake / mm per min on the y-axis, with a smooth curve of best fit; show the no-fan result as a horizontal dashed line. Graph B: air temperature next to leaves / °C on the x-axis and rate of water uptake / mm per min on the y-axis, with a straight line of best fit. Use scales so that more than half the grid is used in both directions (the axes do not have to start at 0), plot each point as a small cross (x) and label both axes with the quantity and unit.



Exam questions 11 questions • 26 marks

- 1** A student investigates the effect of wind speed on the rate of transpiration of a leafy shoot using a potometer and a fan. (a) State the independent variable. [1] (b) State the dependent variable. [1] (c) State one variable that must be kept constant. [1] [3 marks]

- 2** The shoot is cut and put into the potometer under water. Explain why. [2 marks]

- 3** The student then investigates the effect of air temperature. The table shows the distance moved by the bubble in 5 minutes at 28 °C. Calculate the rate of water uptake at 28 °C. Give the unit. Show your working. **[3 marks]**

Distance moved by the bubble in 5 minutes at 28 °C			
air temperature / °C	distance moved by bubble / mm: 1	distance moved by bubble / mm: 2	distance moved by bubble / mm: 3
28	33	36	33

Answer =

- 4** The mean rate of water uptake was 5.0 mm per min at 22 °C, 6.8 mm per min at 28 °C and 9.0 mm per min at 34 °C. The wind speed was kept the same. Describe the effect of temperature on the rate of water uptake. **[2 marks]**

- 5** Supplement. Explain why the rate of transpiration increases as the temperature increases. **[2 marks]**

- 6** Use the data in question 4 to estimate the rate of water uptake at 31 °C. Show how you worked it out. **[2 marks]**

- 7** Supplement. Explain why the rate of transpiration is faster when the fan is closer to the shoot. **[2 marks]**

8 Before the experiment, petroleum jelly is spread over the lower surface of every leaf on the shoot. Predict the effect on the rate of water uptake and give a reason. **[2 marks]**

9 Describe how you would use the potometer to investigate the effect of temperature on the rate of water uptake. **[4 marks]**

10 The potometer measures the water taken up by the shoot, not the water lost by transpiration. Suggest why these are not exactly the same. **[2 marks]**

11 Describe two safety precautions that should be taken in this investigation. **[2 marks]**

Teacher answers

Practical skill 9: Temperature, wind speed and transpiration. The example results are practice data, not real measurements.

Example results

Example results (practice data): distance moved by the air bubble in 5 minutes							
part	distance of fan or hair dryer from shoot / cm	air temperature next to leaves / °C	distance moved by bubble / mm: 1	distance moved by bubble / mm: 2	distance moved by bubble / mm: 3	mean distance moved / mm	rate of water uptake / mm per min
A (no fan)	–	21	12	14	13	13	2.6
A (fan)	100	21	18	16	20	18	3.6
A (fan)	50	21	26	22	24	24	4.8
A (fan)	25	21	31	34	34	33	6.6
B (cool setting)	50	22	24	26	25	25	5.0
B (low heat)	50	28	33	36	33	34	6.8
B (high heat)	50	34	46	43	46	45	9.0

Conclusion

The rate of water uptake increased as the fan was moved closer to the shoot, from 2.6 mm per min with no fan to 6.6 mm per min with the fan 25 cm away, while the air temperature stayed at 21 °C. With the wind speed kept the same, the rate also increased as the air temperature rose, from 5.0 mm per min at 22 °C to 9.0 mm per min at 34 °C. This supports the hypothesis: a higher wind speed and a higher temperature both increase the rate of transpiration. Supplement: moving air blows away the water vapour near the stomata, so the concentration gradient stays steep and water vapour diffuses out of the leaf faster. A higher temperature makes water evaporate faster from the mesophyll cells and water vapour diffuse faster. The potometer measures water uptake, which is slightly more than the water lost, because some water is used in the plant, so the results are an estimate of the rate of transpiration.

Errors and improvements

Error	Effect on the results	Improvement
Air gets into the xylem or the joints leak.	Water is not drawn up properly, so the bubble moves less and the rate is too low.	Cut the shoot and assemble the potometer under water, and seal the joints with petroleum jelly.
In Part B the hot air is drier as well as warmer, and the air speed may change slightly between heat settings.	Part of the change in rate may be caused by humidity or wind speed, not only by temperature.	Keep the hair dryer at the same distance and fan speed, and state this as a limitation; a better method uses a temperature-controlled room or cabinet with the same light and humidity.
Readings are taken before the shoot has adjusted to the new condition.	The first reading in each condition is too low or too high (anomalous).	Leave the shoot for 5 minutes after each change before taking readings, and ignore anomalous readings when calculating the mean.
The position of the bubble is read by eye to the nearest 1 mm, and the stop-clock is started by hand.	Random errors in each reading.	Read the same edge of the bubble at eye level, measure over a longer time and calculate a mean of three or more readings.
The shoot takes up a little more water than it loses, because some water is used in the plant.	The rate of uptake is slightly higher than the true rate of transpiration.	State this in the evaluation. The same shoot is used throughout, so the comparisons are still fair.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [3]

- (a) wind speed (1) allow distance of the fan from the shoot
- (b) distance moved by the bubble in a set time (1) allow rate of water uptake / rate of transpiration
- (c) any one from: same shoot / same number of leaves / same light intensity / same temperature / same humidity / same time for each reading (1) ignore 'same amount of water'

2. [2]

- to stop air entering the xylem (1)
- air would break the column of water / stop water being drawn up the xylem (1)

3. [3]

- mean = $(33 + 36 + 33) \div 3 = 34$ (mm) (1)
- rate = $34 \div 5$ (1)
- 6.8 mm per min (1) unit required; allow mm / min or mm min^{-1}

4. [2]

- the higher the temperature, the faster the rate of water uptake (1) allow positive correlation
- quotes paired figures, e.g. 5.0 mm per min at 22 °C rising to 9.0 mm per min at 34 °C (1)

5. [2]

- water evaporates faster from the surfaces of the mesophyll cells (1) allow water molecules have more (kinetic) energy
- water vapour diffuses out through the stomata faster (1)

6. [2]

- 31 °C is halfway between 28 °C and 34 °C, so $(6.8 + 9.0) \div 2$ (1) allow read from a graph
- 7.9 mm per min (1) allow 7.8–8.0

7. [2]

- (faster) moving air blows water vapour away from around the stomata / leaf surface (1)
- keeps the concentration gradient (of water vapour) steep, so diffusion out of the leaf is faster (1)

8. [2]

- the rate decreases / the bubble moves less (1) reject stops completely
- the stomata (on the lower surface) are blocked, so less water vapour can leave the leaves (1)

9. [4]

- change the temperature, e.g. a heater or hair dryer at different heat settings at a fixed distance (1)
allow rooms at different temperatures
- measure the air temperature next to the leaves with a thermometer (1)
- measure the distance moved by the bubble in a set time, e.g. 5 minutes (1)
- keep the wind speed / light intensity / shoot the same (1)
- leave the shoot to settle at each temperature before measuring (1)
- repeat at each temperature and calculate a mean (1)
- Max 4

10. [2]

- some water is used in photosynthesis (1)
- some water stays in the cells / keeps cells turgid / is used for growth (1)
- allow water may leak from the apparatus (1)
- Max 2

11. [2]

- keep the fan / hair dryer / mains cables away from water / stand the potometer in a tray (1)
- clear up spills at once (1)
- do not touch the hot nozzle of the hair dryer / clamp it (1)
- cut the shoot away from the fingers on a tile / take care with the glass tube (1)
- Max 2

Exam tips

- Cut the shoot under water to stop air entering the xylem. Examiners reward this exact reason.
- Write rate = distance $\div$ time and give the unit, for example mm per min. A missing unit loses the mark.
- Change only one factor. When you change the temperature, keep the wind speed and the light the same, and measure the temperature next to the leaves.
- Supplement: explain wind speed by saying that moving air removes water vapour from near the stomata, which keeps the concentration gradient steep.
- Head columns in the form quantity / unit, for example time / min, and leave units out of the body of the table.