

# Environmental factors and transpiration

investigate the role of environmental factors in determining the rate of transpiration from a leafy shoot

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** This practical is not in the Double Award and is only examined on Paper 2. Teacher answers start on a new page.

Name .....

Date .....

## Aim

To investigate how an environmental factor, wind speed, affects 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, mainly through the stomata. Water evaporates from the surface of the mesophyll cells into the air spaces and then diffuses out through the stomata.

Almost all of the water taken up by a plant is lost by transpiration. A **potometer** measures the water taken up by a cut shoot, so uptake is used as a measure of the rate of transpiration. The bubble in the capillary tube moves towards the shoot as water is taken up.

Four environmental factors change the rate of transpiration. A higher temperature, a higher wind speed and a higher light intensity all increase it. Higher humidity decreases it, because the concentration gradient of water vapour between the leaf and the air is smaller.

## Hypothesis

As wind speed increases, the rate of transpiration will increase, because moving air carries water vapour away from the stomata and keeps a steep concentration gradient.

## Variables

|                    |                                                                                                                                                                                                                                                                                                                                                     |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Independent</b> | Wind speed, changed by the distance between a fan and the shoot (no fan, 100 cm, 50 cm, 25 cm)                                                                                                                                                                                                                                                      |
| <b>Dependent</b>   | The distance moved by the air bubble in 5 minutes (mm), used to calculate the rate of water uptake (mm/min)                                                                                                                                                                                                                                         |
| <b>Control</b>     | <ul style="list-style-type: none"><li>• The same shoot with the same number and size of leaves</li><li>• Light intensity and the position of the lamp</li><li>• Temperature of the room and the water</li><li>• Humidity of the air around the shoot</li><li>• Time for each reading, 5 minutes</li><li>• Starting position of the bubble</li></ul> |

## Equipment

- Potometer (a capillary tube with a ruler fixed beside it, a reservoir with a tap, and a holder for the shoot)
- A leafy shoot, about 20 cm long, from a plant such as privet, willow or geranium
- Beaker or bowl of water, to cut and assemble the potometer under water

- Secateurs or a sharp knife
- Petroleum jelly
- Paper towels
- Electric fan with a speed control
- Metre rule, to measure the distance of the fan from the shoot
- Stopclock
- Syringe
- Tray for water spills

## Risk assessment

| Hazard                                             | Risk                                                  | Precaution                                                                                                                                          |
|----------------------------------------------------|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Cutting the shoot with secateurs or a knife</b> | Cuts to the hand.                                     | Cut away from the body on a firm surface, or ask your teacher to cut the shoot. Use secateurs rather than a knife where possible.                   |
| <b>Water near the electric fan</b>                 | Electric shock if water spills on to the fan or plug. | Keep the fan and its cable away from water, stand the potometer in a tray, and clear any spills straight away. Do not touch the fan with wet hands. |
| <b>Glass capillary tube</b>                        | Cuts if it breaks.                                    | Handle with care. Do not push the glass into rubber tubing without a lubricant and a cloth. Report breakages.                                       |
| <b>Slippery floor</b>                              | Slipping on spilt water.                              | Work in a tray and mop up spills immediately.                                                                                                       |
| <b>Plant sap</b>                                   | Some plants irritate the skin.                        | Wash hands after handling the plant. Do not taste any plant material.                                                                               |

## Method

1. Fill a bowl with water. Cut a leafy shoot under water so that no air gets into the xylem, and cut the end at a slant.
2. Assemble the potometer under water, so that the apparatus is full of water, and push the cut end of the shoot into the holder under water.
3. Lift the potometer out of the water and check that there are no air bubbles in the apparatus and that all the joints are airtight. Seal the joints with petroleum jelly if needed.
4. Dry the leaves of the shoot gently with a paper towel. Wet leaves would change the rate of water loss.
5. Keep the end of the capillary tube in a beaker of water. Remove the end from the water for a moment to let one air bubble enter, then put it back.
6. Use the reservoir tap or a syringe to position the bubble at the start of the scale. Wait 5 minutes for the shoot to settle.
7. With no fan, record the starting position of the bubble and start the stopclock.
8. After 5 minutes, record the position of the bubble. Calculate the distance moved.
9. Move the bubble back to the start of the scale using the reservoir, and repeat steps 7 and 8 twice more for no fan.

- L0 . Place the fan 100 cm from the shoot, switch it on, wait 5 minutes and measure the distance moved by the bubble in 5 minutes, three times.
- L1 . Repeat step 10 with the fan 50 cm and then 25 cm from the shoot. Keep the speed setting of the fan the same.
- L2 . Calculate the mean distance moved for each fan distance.
- L3 . Calculate the mean rate of water uptake for each fan distance using: rate = distance moved by bubble ÷ time.
- L4 . Plot a graph of the rate of water uptake against the distance of the fan.

## Results

| Distance moved by the air bubble in 5 minutes |                             |                             |                             |                          |                               |
|-----------------------------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------|-------------------------------|
| Distance of fan from shoot (cm)               | Distance moved, test 1 (mm) | Distance moved, test 2 (mm) | Distance moved, test 3 (mm) | Mean distance moved (mm) | Rate of water uptake (mm/min) |
| No fan                                        |                             |                             |                             |                          |                               |
| 100                                           |                             |                             |                             |                          |                               |
| 50                                            |                             |                             |                             |                          |                               |
| 25                                            |                             |                             |                             |                          |                               |

## Graph

Line graph with the distance of the fan from the shoot (cm) on the x-axis and the rate of water uptake (mm/min) on the y-axis. Plot the three fan distances (25, 50, 100 cm) and draw a smooth curve of best fit through them. Show the no-fan result as a horizontal dashed line labelled 'no fan'. Do not plot it at 0 cm, because 0 cm would mean the fan right next to the shoot (the fastest wind). The rate is highest at the shortest distance (fastest wind).



## Exam questions 10 questions · 29 marks

- 1** A potometer measures the volume of water taken up by a shoot. Explain why this can be used as a measure of the rate of transpiration. [2 marks]

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

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**3** Give two variables that should be controlled in the investigation. **[2 marks]**

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**4** The air bubble moved 36 mm in 5 minutes. Calculate the rate of water uptake in mm per minute. **[2 marks]**

Answer = .....

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**5** The capillary tube has a cross-sectional area of  $0.8 \text{ mm}^2$ . Calculate the volume of water taken up in 5 minutes when the bubble moves 36 mm, and the rate of uptake in  $\text{mm}^3$  per minute. **[3 marks]**

Answer = .....

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**6** The table shows the results from a student's investigation. Calculate the mean distance moved for the fan at 50 cm. **[3 marks]**

| Distance moved by the bubble in 5 minutes |             |             |             |
|-------------------------------------------|-------------|-------------|-------------|
| Distance of fan (cm)                      | Test 1 (mm) | Test 2 (mm) | Test 3 (mm) |
| 50                                        | 28          | 30          | 29          |
| 25                                        | 37          | 35          | 36          |

Answer = .....

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- 7** Describe the relationship between the distance of the fan from the shoot and the rate of water uptake shown by the data in question 6, and suggest an explanation. **[3 marks]**

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- 8** Predict the effect on the rate of water uptake of putting a clear plastic bag over the shoot, **[3 marks]** and explain your prediction.

[illegible]

- 9** Describe how you would use a potometer to investigate the effect of light intensity on the rate of transpiration of a leafy shoot. Explain the results you would expect. **[6 marks]**

[illegible]

- 10** Suggest two improvements that would make the investigation more accurate, and explain one of them. **[3 marks]**

[illegible]

## Teacher answers

Practical 10: Environmental factors and transpiration. The example results are practice data, not real measurements.

### Example results

| Example results (practice data): distance moved by the bubble in 5 minutes |                             |                             |                             |                          |                               |
|----------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------|-------------------------------|
| Distance of fan from shoot (cm)                                            | Distance moved, test 1 (mm) | Distance moved, test 2 (mm) | Distance moved, test 3 (mm) | Mean distance moved (mm) | Rate of water uptake (mm/min) |
| No fan                                                                     | 15                          | 14                          | 16                          | 15                       | 3.0                           |
| 100                                                                        | 20                          | 22                          | 21                          | 21                       | 4.2                           |
| 50                                                                         | 28                          | 30                          | 29                          | 29                       | 5.8                           |
| 25                                                                         | 37                          | 35                          | 36                          | 36                       | 7.2                           |

### Conclusion

The rate of water uptake increased as the fan was moved closer to the shoot, from 3.0 mm/min with no fan to 7.2 mm/min with the fan 25 cm away. A closer fan gives a higher wind speed at the leaves. Moving air carries water vapour away from the stomata, so the concentration gradient of water vapour between the inside of the leaf and the air stays steep, and water vapour diffuses out faster. The shoot loses water faster by transpiration, and water is pulled up the xylem faster to replace it, so the bubble moves further. This supports the hypothesis. The potometer measures water uptake, which is a measure of the transpiration rate. Not all the water taken up is lost (a little is used in photosynthesis and for support), so uptake is only an approximate measure.

## Errors and improvements

| Error                                                                                                | Effect on the results                                                                                                                                                                   | Improvement                                                                                                                                            |
|------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Air bubbles get into the xylem of the shoot or the apparatus, or the joints leak.                    | Water cannot be drawn up properly and the bubble movement gives a rate that is too low.                                                                                                 | Cut the shoot and assemble the potometer under water, and check and seal the joints with petroleum jelly.                                              |
| Other conditions (light, temperature, humidity) change during the experiment.                        | The rate changes for reasons other than the fan, so the results are not valid.                                                                                                          | Keep the apparatus in the same place, use a water tank as a heat shield if a lamp is used, and let the shoot settle for 5 minutes between each change. |
| Water is left on the leaves after cutting under water.                                               | Water evaporates from the leaf surface instead of from inside the leaf, and the film of water can cover stomata, so the uptake measured is lower and less consistent than it should be. | Dry the leaves gently with paper before the experiment.                                                                                                |
| The bubble position is read incorrectly against the scale, and timing is by hand.                    | Random errors of about 1 to 2 mm affect each reading.                                                                                                                                   | Read the same part of the bubble each time at eye level, use longer times, and repeat to calculate a mean.                                             |
| Water is used in photosynthesis and for support, so uptake is not exactly the same as transpiration. | The potometer slightly overestimates the transpiration rate.                                                                                                                            | Mention this in the evaluation. The error is small, and the same shoot is used each time, so comparisons are still valid.                              |

## Mark scheme

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

### 1. [2]

- almost all the water taken up by the shoot is lost by transpiration (1)
- so the volume taken up in a given time is nearly equal to the water lost / the rate of uptake equals the rate of transpiration (1)

### 2. [2]

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

### 3. [2]

- same shoot / leaf area (1)
- same light intensity (1)
- same temperature (1)
- same humidity (1)
- same time for each reading (1)
- Max 2

### 4. [2]

- $36 \div 5$  (1)
- 7.2 mm/min (1) unit required

**5. [3]**

- volume =  $0.8 \times 36$  (1)
- $28.8 \text{ mm}^3$  (1)
- $28.8 \div 5 = 5.76 \text{ mm}^3/\text{min}$  (1) allow  $5.8 \text{ mm}^3/\text{min}$

**6. [3]**

- $28 + 30 + 29 = 87$  (1)
- $87 \div 3$  (1)
- 29 mm (1) unit required

**7. [3]**

- the closer the fan, the faster the water uptake / more distance moved by bubble (1)
- closer fan means higher wind speed (1)
- moving air removes water vapour from the stomata, keeping a steep concentration gradient so more water leaves the leaf (1)

**8. [3]**

- rate decreases (1)
- humidity around the leaves increases (1)
- so the concentration gradient of water vapour is less steep, and diffusion out of the leaf is slower (1)

**9. [6]**

|                              |                                                                                                                                                                                                                              |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Level 3</b><br><b>5-6</b> | A full method with the apparatus set up correctly, a clear independent and dependent variable, several light intensities, controls and repeats, and an explanation of the expected result in terms of stomata and diffusion. |
| <b>Level 2</b><br><b>3-4</b> | A method with the potometer and a way of changing light, with some measurements or controls. Explanation incomplete.                                                                                                         |
| <b>Level 1</b><br><b>1-2</b> | A few relevant points, for example a shoot in a potometer and a lamp, with little detail.                                                                                                                                    |

**Indicative content**

- cut shoot under water and set up the potometer with no air bubbles; introduce an air bubble and record its position
- change the distance of a lamp from the shoot to alter light intensity (with a heat shield)
- measure the distance moved by the bubble in a set time at each distance; calculate rate = distance  $\div$  time
- control: same shoot, temperature, humidity, wind, time; repeat and calculate a mean
- expected: greater rate at higher light intensity
- stomata open wider in the light, so more water vapour diffuses out; faster transpiration pulls more water up the xylem

**10. [3]**

- repeat the tests and calculate a mean / use more repeats (1)
- measure for a longer time or use a narrower capillary tube (1)
- explanation: for example, repeats reduce the effect of random errors / a longer time gives larger distances so the percentage error in reading is smaller (1)
- allow other valid suggestions, such as wait for the shoot to adjust to each change

## Exam tips

- Explain why the potometer works: the bubble moves because water is pulled up the xylem as water is lost from the leaves by transpiration.
- Rate = distance  $\div$  time, and always include the unit (mm/min). For volume, multiply the cross-sectional area by the distance moved.
- Name the specific environmental factor and say whether the rate increases or decreases, with a reason in terms of the concentration gradient or the stomata.
- Say that the shoot is cut under water to stop air getting into the xylem. Examiners reward this exact reason.
- Humidity is the factor students most often get wrong: high humidity means a smaller concentration gradient, so the rate decreases.